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Is a Re-evaluation of WHO Body Mass Index Cut-off Values Needed? The Case of Asians in Singapore

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This paper describes body composition and dietary intakes of the three major ethnic groups residing in Singapore and how these are related to cardiovascular risk factors in these groups. When the relationship between body mass index (BMI, kg/m^2) and body fat percentage was studied, Singaporeans were found to have higher percentage of body fat compared with Caucasians with the same BMI. At BMIs that are much lower than WHO-recommended cut-off values for obesity, both the absolute and relative risks of developing cardiovascular risk factors are markedly elevated for all three ethnic groups. The excessive fat accumulation and increased risks at lower BMIs signal a need to re-examine cut-off values for obesity among Chinese, Malays, and Indians.

Key words: body mass index, Asian, WHO

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Introduction

In recent years, studies have shown that body fat percentage–body mass index (BMI, kg/m^2) relationships are age and sex specific to[1–5] and likely ethnicity.[6–10] For example, Indonesians are found to have a higher body fat percentage compared to Caucasians with the same BMI.[9] For the same body fat percentage, differences in BMI between Indonesians and Caucasians are approximately three units. This would imply that, based on body fat percentage, the BMI cut-off points for obesity in Indonesia should be 27 instead of 30.

Singapore is a multi-ethnic, multi-cultural society comprising mainly Chinese (77%), Malays (14%), and Indians (7%). Over the last four decades, Singapore has experienced a rapid economic growth with concomitant improvement in health status of her people. The infant mortality rate is among the lowest in the world at less than 3 per 1000 live births, whereas life expectancy at birth has risen to 80 years for women and 76 years for men.[11]

A change in the disease patterns among Singaporeans has paralleled these favorable changes. The main causes of deaths shifted from infectious diseases and poor environmental conditions to so-called diseases of lifestyle. Today, cancers and cardiovascular diseases (mainly coronary heart disease) are the two major causes of death.

Mortality from cardiovascular disease in Singapore is comparable to those of the West and higher than those in other parts of Asia, such as Japan and Hong Kong.[12] On the other hand, obesity prevalence (defined as BMI ≥30) is much lower among Singaporean adults at approximately 5% compared with Caucasian populations.[13]

Such a discrepancy in the apparently low prevalence of obesity and high prevalence of obesity-related diseases in Singapore could be the result of inappropriate BMI cut-off points.

From the National Health Survey conducted in 1992[14] and studies by Hughes et al.,[15–17] data suggest that cardiovascular risk factors differ in the three major ethnic groups in Singapore. Such risk factors include obesity, abdominal adiposity, elevated blood pressure, abnormal blood lipids (elevated total cholesterol and LDL-cholesterol and low HDL-cholesterol levels), and elevated blood glucose and insulin.

The role of diet in cardiovascular diseases is well documented. A diet that is high in energy, total fat, saturated fat, and cholesterol, and relatively low in unsaturated fats, fruits, and vegetables is linked to the development of cardiovascular diseases.[18–20]

Editors Note: This paper was presented in the ILSI Japan symposium entitled, "International Symposium on Glycemic Carbohydrate and Health." Although not directly related to the main topic of the symposium, this paper should prove interesting to our readers. Please see the March 2003 issue of Nutrition Reviews (Stevens J, Nowicki EM. Body mass index and mortality in Asian populations: implications for obesity cut-points. Nutr Rev. 2003;61:104–107) for additional discussion of body mass index cut-off values in Asian populations.

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There is a paucity of studies examining the dietary intakes among Singaporeans and how these could be related to cardiovascular risk factors in Singaporeans.[21] The first food consumption study in Singapore was conducted in 1993 among some 470 adult Singaporeans. From that study, selected dietary practices and population mean intakes (using 24-hour dietary recalls and three-day weighed food records) of energy and nine nutrients for the different ethnic, age, and sex sub-groups were determined.[22] Unfortunately, no information on risk factors among the subjects was available.

Currently, there is no satisfactory explanation for the high prevalence of cardiovascular diseases in Singapore and the differences in prevalence among the different ethnic groups. There is a lack of data on dietary intakes and body composition among different ethnic groups in Singapore and how these contribute to differences observed in cardiovascular risk factors. Therefore, detailed studies on dietary intakes and body composition were conducted as part of the National Health Survey in 1998 (NHS 98),[23] a cross-sectional survey to determine the prevalence of selected diseases and their associated risk factors. From the main sample of the NHS 98, subsamples were selected to participate in the dietary (n = 2400) and body composition (n = 291) components of the present study. The Ministry of Health of Singapore funded the main National Health Survey while the National Medical Research Council of Singapore funded the sub-sample studies. There were two main objectives:

1. To define the BMI cut-off values for obesity based on body fat percentage and cardiovascular risk factors, and
2. To study relationship between diet and cardiovascular risk factors among the major ethnic groups (Chinese, Malays, and Indians) in Singapore.

BMI and Body Fat Percentage

To accurately measure the body fat percentage in the study population, it was necessary to select a methodology free of assumptions and regarded as a gold standard. For this, the four-compartment model described by Baumgartner et al.[24] was used. In this model the body is divided into fat mass, minerals, water, and a fourth compartment comprising protein and glycogen. Each of the latter three components was determined individually using dual-energy X-ray absorptiometry, deuterium oxide dilution, and densitometry, respectively. The difference between body weight and these three components yields the actual fat mass of the individual. Detailed methodology has been previously described.[25]

The relationship between body fat percentage (BF%) and BMI was examined in 291 subjects, of whom 108 were Chinese, 76 were Malays, and 107 were Indians. Their ages ranged from 18 to 75 years and their BMI from 16 to 40. Investigators found that when a BF% prediction equation based on BMI developed in Caucasians was applied to the three ethnic groups in Singapore, actual BF% as measured by the reference method was grossly underestimated. The bias in prediction ranged from 2.7% to 5.6% body fat. This indicates that the BMI-BF% relationships in Chinese, Malays, and Indians are different from that of Caucasian populations. This relationship in Singaporeans is described as:

$$\mathrm{BF\%} = (1.04 \times \mathrm{BMI}) - (10.9 \times \mathrm{sex}) + (0.1 \times \mathrm{age}) + 2.0E_1 + 1.5E_2 + 5.7$$

where the 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 $E_1 = 1$, $E_2 = 1$). Sex is coded as 0 for females and 1 for males.

For the same BMI values, therefore, Chinese have the lowest BF% whereas Indians have the highest. This equation above explains 74% of the variation in BF% and has a standard error of estimate of 4.4% body fat, which is comparable to BMI-based prediction formulas in current literature.[26,27] For the same BF% as obese Caucasians with a BMI of 30, the BMI of Chinese and Malays should be approximately 27 whereas that for Indians should be approximately 26. The value for Malays is similar to those found in studies done among Indonesians in Indonesia.[9,26]

Relationship between BMI and Cardiovascular Risk Factors

A total of 4723 subjects (64% Chinese, 21% Malays, and 15% Indians, with equal numbers of males and females) from the 1998 National Health Survey were studied for the relationship between selected cardiovascular risk factors and BMI. All subjects went through a thorough interviewer-administered questionnaire and a series of physical examination and blood tests (fasting and two hours post-prandially).

All biochemical parameters were performed using standardized protocols. Physical measurements were done according to published protocols from WHO.[28,29] Details of the study design, including all procedures and tests have been previously documented.[30]

Cut-off values for hypertension were defined as systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg,[31] elevated total cholesterol (TC) as TC ≥6.2 mmol/L, elevated TC/HDL cholesterol ratio as ≥4.4 mmol/L,[32] elevated triglyceride as TG ≥1.4 mmol/L,[33] and diabetes mellitus as oral glucose tolerance test (OGTT) ≥11.1 mmol/L.[34] Risk was defined as having at least one of the above risk factors.

The absolute and relative risks for at least one cardiovascular risk factor—elevated total blood cholesterol, elevated total cholesterol-to-HDL cholesterol ratio, elevated triglycerides, hypertension, or diabetes mellitus—were determined for various categories of BMI, with correction for age, waist-to-hip ratio, cigarette smoking, physical activity level, educational level, and occupation

For all ethnic groups, at low categories of BMI the absolute risks are high (Figure 1). At these same BMI categories the relative risks (RR) for having at least one cardiovascular risk factor was significantly higher compared with the reference category (Figure 2). For example, at a BMI as low as 22 to 24, the RR is as high as 2.22 in females and 3.14 in males. This BMI category is below the cut-off values of BMI for overweight as currently recommended by WHO.[13]

The marked increase in absolute and relative risks with increasing categories of obesity indices is consistent with the high mortality from ischemic heart disease experienced by Singaporeans. The discrepancy between the high cardiovascular mortality and apparently low national obesity prevalence (defined as BMI $\geq$30) could be partially explained by the presence of excessive body fat percent among Singaporeans at low levels of BMI when compared with Caucasians. Based on BF% and presence of risk factors, the currently recommended BMI cut-off values for overweight ($\geq$25) and obesity ($\geq$30) are likely not to be relevant for Singaporeans. BMI cut-off values of $\geq$23 and $\geq$27 for overweight and obesity, respectively, 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 have already at least one risk factor. The RR of having at least one risk factor would be moderately increased for overweight men and women (RR between 2 and 3) and greatly increased for obese men and women (RR >3). The consequence of lowering BMI cut-off values for overweight and obesity from 25 and 30 to 23 and 27, respectively, 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%.

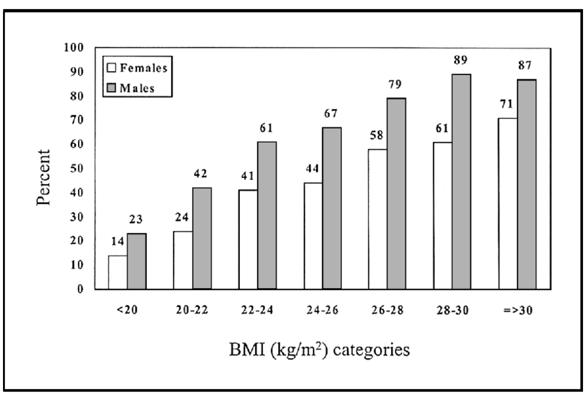

Figure 1. Proportion of Singaporean adults with at least one cardiovascular risk factor by gender and body mass index (BMI) categories.

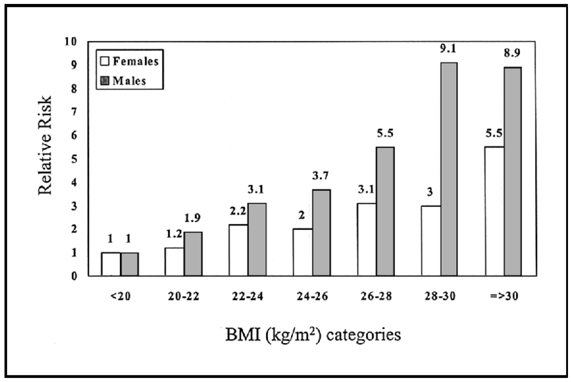

Figure 2. Relative risk of having one risk factor by gender and body mass index (BMI) categories (corrected for age, ethnic group, educational level, occupation, physical activity, smoking, and waist-to-hip ratio).

Diet and Cardiovascular Risk Factors

A validated food-frequency questionnaire[35] was used to assess usual intakes (over a period of one month) of energy, total fat, types of fats, cholesterol, fruits, vegetables, and rice and alternatives among 2408 (61.0% Chinese, 21.4% Malays, and 17.6% Indians) subjects randomly selected from the NHS 98 main sample. The intakes of fat, saturated fat, polyunsaturated fat, and monounsaturated fat were also expressed as percent of total energy intake (%fat, %SFA, %PUFA, %MUFA, respectively) and cholesterol intake as cholesterol (mg) per 1000 kcal of energy. Hegsted score[36] ([2.16 $\times$ %SFA] $-$ [1.65 $\times$ %PUFA] $+$ [0.0677 $\times$ cholesterol] $-$ 0.53) was computed to assess the cholesterolemic effect of the diet.

Generally, it was found that the intakes of food types and nutrients were fairly homogenous among the three ethnic groups in Singapore. Overall, the diet of Singaporeans is low in fruits and vegetables and whole grain products. The fat intake (at about 27% of total energy intake for both males and females) is within the recommended upper limit (30% of total energy), but the intake of saturated fat is higher than the recommended 10% of total energy with corresponding lower intakes of polyunsaturated fat and monounsaturated fat (Table 1). Such a dietary profile has been found to correspond to risk for coronary heart disease on a population level.[37,38]

On a group level, the mean intakes of each gender-ethnic group were highly correlated with mean serum cholesterol. Total serum cholesterol was positively correlated with Hegsted score (r = 0.77) and intake of rice and alternatives (r = 0.60) and negatively correlated with vegetables (r = $-$0.82). The total cholesterol-to-HDL cholesterol ratio was positively correlated with Hegsted score (r = 0.67), rice and alternatives (r = 0.70), and fat intake (r = 0.60). HDL cholesterol level was negatively correlated with fat intake (r = $-$0.70) and rice and alternatives (r = $-$0.63). The adverse effect of rice and alternatives on serum

Table 1. Distribution of Selected Dietary Intakes by Gender and Ethnic Groups

	Chinese		Malays		Indians		All	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Females								
Energy (kcal)	1812*	606	1902*	641	2081†	710	1879	640
Total fat (g)	55.2*	24.5	60.5†	26.4	66.3†	28.9	58.2	26.0
% fat	26.8*	5.4	27.9†	5.4	28.2‡	5.4	27.3	5.4
% SFA	10.1*	2.5	11.6†	2.9	11.5†	2.9	10.7	2.8
% MUFA	9.3*	2.3	9.1*	2.3	8.0†	2.3	9.0	2.4
% PUFA	5.6*	2.2	5.1†	2.2	6.2‡	2.6	5.6	2.3
Protein (g)	63.5	23.2	61.4	22.4	63.0	21.1	63.0	22.7
Chol (mg)	222*	114	236*	122	197†	115	220	116
Chol (mg)/1000 kcal	120*	42	121*	41	92†	38	116	43
Hegsted[35] score	14.7*	7.7	15.6*	8.3	12.9†	7.8	14.6	7.9
Fruits (servings)	1.24	0.97	1.28	1.10	1.37	0.94	1.27	0.99
Vegetables (servings)	1.27*	0.79	1.22*	0.92	1.42†	0.65	1.29	0.79
Rice & alternatives (servings)	5.42*	1.88	5.48	2.27	5.84†	1.96	5.51	1.97
Males								
Energy (kcal)	2337	777	2340	799	2358	704	2341	769
Total fat (g)	70.2	31.2	73.5	34.7	72.2	28.3	71.3	31.5
% fat	26.5*	5.4	27.6†	6.4	27.2	5.4	26.8	5.6
% SFA	10.4*	2.5	11.8†	3.2	11.3†	3.0	10.9	2.8
% MUFA	9.2*	2.3	9.0*	2.6	8.1†	2.2	9.0	2.4
% PUFA	4.9*	1.7	4.4†	1.7	5.5‡	2.2	4.9	2.3
Protein (g)	70.4	31.5	80.4	33.8	74.5	48.8	76.2	29.5
Chol (mg)	294*	148	295*	164	244†	141	285	151
Chol (mg)/1000 kcal	124*	39	123*	43	103†	45	120	42
Hegsted[35] score	19.5*	10.1	19.6*	11.1	16.2†	9.5	18.9	10.3
Fruits (servings)	1.32*	1.01	1.26	1.30	1.56†	1.09	1.35	1.09
Vegetables (servings)	1.36	0.86	1.30	0.81	1.41	1.05	1.36	0.90
Rice & alternatives (servings)	7.23	2.39	7.08	2.55	6.97	2.89	7.15	2.54

*†‡For each row, different alphabets indicate significant difference between ethnic groups (P <0.01, ANCOVA with age as covariate). % fat = % energy as fat, % SFA = % energy as saturated fatty acids, % MUFA = % energy as monounsturated fatty acids, % PUFA = % energy as polyunsaturated fatty acids, Chol = cholesterol.

cholesterol levels is likely to be due to the low proportion of whole grain products consumed and also to the method of preparation. Both rice and noodles, the staple foods of Singaporeans, are often prepared with high fat and/or saturated fat ingredients that are the main sources of fat and saturated fat, contributing to 14% of total fat intake and 15% of total saturated fat intake to the diet of adult Singaporeans.[39]

On the individual level, however, these dietary factors did not explain the differences in serum cholesterol levels between the ethnic groups. Dietary factors could account only for less than 1% of the differences in total serum cholesterol, HDL-cholesterol, LDL-cholesterol, and total cholesterol-to-HDL cholesterol ratio after the effects of age, BMI, waist-to-hip ratio, activity levels, cigarette smoking, and occupation were taken into account.

Discussion

The different relationship between BMI and BF% among the different ethnic groups as compared to Caucasians was also found in some recent studies. In a meta-analysis[10] data showed that for the same level of BF%, age, and sex as Caucasians, the BMI of American Blacks and Polynesians were 1.3 and 4.5 higher, whereas BMI for Chinese, Ethiopians, Indonesians, and Thais were 1.9, 4.6, 3.2, and 2.9 lower, respectively. In practical terms, it would mean that for Polynesians, BMI cut-off point for obesity should be as high as 34.5 while that for Indonesians should be only 26.8. Unfortunately, data from this meta-analysis are not conclusive, as different methods used to measure BF% in the various study groups could have contributed to the differences in BMI-BF% relationship between groups.

The present study has overcome the problems of the afore-mentioned studies by using an accepted reference method for all ethnic groups studied. Additional anthropometric measurements have shown that body build (slenderness and leg lengths) could partially explain differences in relationship between groups. Thus the evidence that Singaporeans have a high BF% at a low BMI is strong and non-ambiguous. The indication that BMI cut-off points for overweight and obesity should be lowered in Singaporeans is further supported by the demonstration of markedly elevated absolute and relative risks for cardiovascular risk factors at BMI levels that are much lower than those currently recommended by WHO for obesity.[13]

The food-frequency questionnaire was chosen as the dietary tool to be used in this study because the intention was to be able to classify subjects into quintiles of intakes for energy, fat, types of fat, and cholesterol for epidemiologic studies. In addition, it was to be able to quantify intakes of fruits, vegetables, and grain foods. After the validation study, it was found to be able to serve the above purposes adequately for the three ethnic groups.

As for other cross-cultural studies involving diet and cardiovascular risks (and mortality), such as the Seven Countries Study[40] and the MONICA study,[41] the high group mean intakes of fat, saturated fat, polyunsaturated fat, and cholesterol, and low intake of vegetables were found to be inversely correlated with serum cholesterol. At the individual level, on the other hand, dietary intakes as measured by the food-frequency questionnaire could not explain the differences in serum cholesterol levels between the ethnic groups after adjustment for other possible confounders. However, this does not imply that these factors are not important determinants of coronary heart disease risks. One of the reasons that dietary factors could not explain the difference in serum cholesterol among ethnic groups may be the fairly homogenous intakes of the selected nutrients and food types between individuals.[42] There are only slight differences throughout the range of intakes (Figures 3 and 4). Another reason is that determinants of disease at the individual level are not necessarily the same as those at population level.[43] Correlations between factors and disease (risks) found at cross-country studies could be confounded by a multitude of other factors, including genetic, cultural, environmental, and lifestyle factors.[44] Another consideration that has to be taken into account is the composition of saturated fat in the diet and the presence of other modulating or potentiating factors. It is now known that not all saturated fats are equally cholesterolemic and the saturated fat effect is related to the dietary cholesterol load and lipoprotein metabolism (or lipoprotein set point) of the individual.[38,45,46] Recent literature suggests that high intakes of fruits and vegetables can modulate the effects of dietary fat[47] and international comparative studies indicate that consumption of fruit, vegetables, and whole grains is inversely correlated to mortality from heart disease, possibly by mediating their effects through dietary fiber and a combination of other non-nutrients such as phytoestrogens (e.g., lignans) and antioxidants (e.g., vitamin E).[48,49] Thus the actual quantification of the role of a single nutrient or food component in serum cholesterol requires in-depth studies of interactions between nutrients and food components.

Admittedly, the food-frequency questionnaire is not meant for the detection of individual intakes and, as such, could be one of the reasons why dietary factors were shown to contribute to only 1% of the differences in serum cholesterol levels among the three ethnic groups. A more robust method to measure actual individual intakes would be the dietary history method or the multiple food intake recall or record method, preferably covering different seasons in a year.[50] The main purpose of the food-frequency questionnaire, besides being able to classify subjects into levels of intakes for correlation with risk factors, was to be a dietary tool for the monitoring of trends of intakes of various food types, fat, types of fats, and cholesterol on a group level, and how this change contributes to changes in risk factors. For example, the cholesterolemic effect of dietary intakes could be estimated using a suitable score such as Hegsted

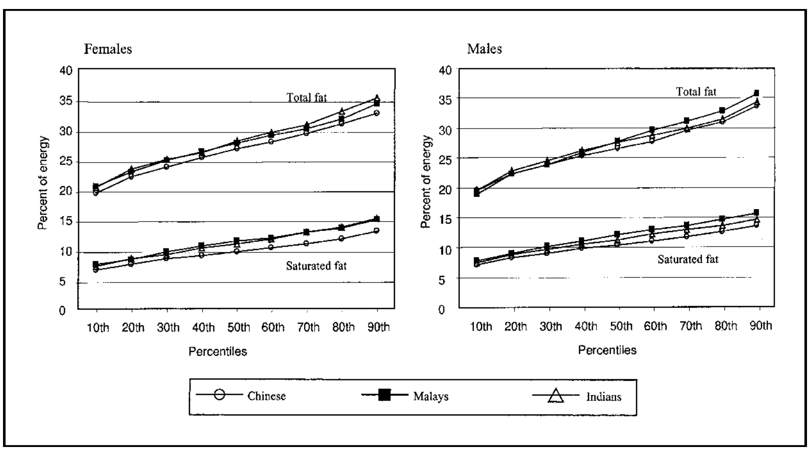

Figure 3. Distribution of subjects by percentiles of fat and saturated fat intakes (percent of energy) by gender and ethnic group.

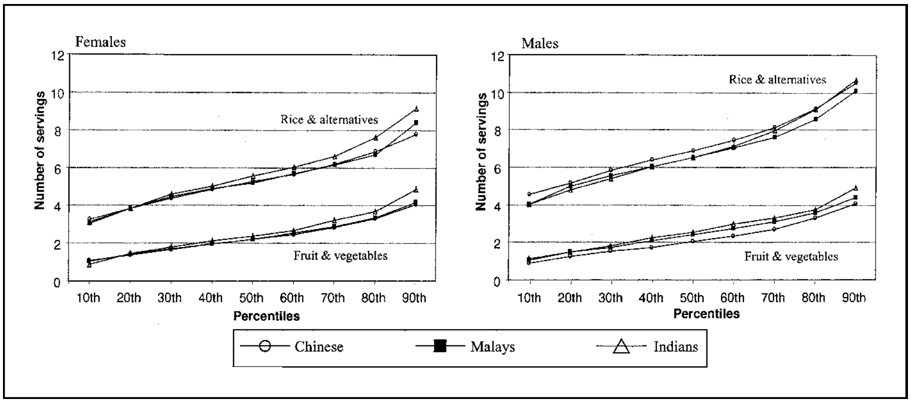

Figure 4. Distribution of subjects by percentiles of intakes of rice and alternatives and fruits and vegetables (servings per day) by gender and ethnic group.

score.[36] By monitoring the main food sources of fat, types of fat, and cholesterol, it would enable the formulation of more specific nutrition education messages for the different population groups.

One major drawback of the present dietary study is its cross-sectional nature. Because it is the first of such studies done on a national scale in Singapore, it forms the baseline from which a prospective study can be carried out as part of the National Health Survey, which is conducted regularly. Such a prospective study would be able to investigate the influences of changes in dietary and other lifestyle factors on disease risks and provide better evidence on how these could be addressed to lower the individual and population risks.

Implications of Findings and Recommendations

The current study could not find the association between dietary factors and serum cholesterol levels, mainly owing to insufficient interperson variation and its cross-sectional nature. The latter limitation also applies to other risk factors like obesity, abdominal fatness, smoking, hypertension, and physical activity patterns.

To be able to quantify the benefits of dietary and other lifestyle changes on lowering serum cholesterol and thereby the mortality from coronary heart disease, longitudinal studies will be necessary. The present study and the two well-standardized National Health Surveys have established the baseline for most of the parameters and risk factors for future follow up. This, in combination with the available mortality statistics, would enable Singapore to estimate the role of changes in risk factors and mortality from coronary heart disease and enable the effective implementation and evaluation of the ongoing Healthy Lifestyle Programme to lower risk factors among Singaporeans.

The study on body composition was undertaken for the first time on a large scale in Singapore and also the region using a referent four-compartment model. The evidence is clear that WHO's cut-off value for obesity is not valid for Singaporeans. Singaporeans have higher level of body fat percent compared with Caucasians at the same level of BMI (after correction for age and sex), and based on body fat percent, the cut-off value for obesity should be approximately 27 instead of 30. This was supported by the markedly elevated absolute and relative risks of having cardiovascular risk factors at low levels of BMI. The risks are also apparent at levels of waist-to-hip ratio and waist circumferences that are below the WHO's recommended cut-off values.

Recently, WHO also recognized that BMI cut-off values for obesity among Asians need to be re-examined owing to preliminary data from various Asian countries such as China (including Hong Kong), India, Japan, Korea, Malaysia, and Indonesia demonstrating that risk factors are manifested at low levels of BMI.[51] The data from the current study, which includes evidence that not only risk factors but also body fat percent 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 that this should be lowered to would depend on the scientific findings of each country, based on the two criteria for the definition of obesity. If BMI cut-off values for obesity were to be lowered, there would be tremendous implications in terms of public health policy for the prevention and management of obesity and its co-morbidities. In Singapore, the overall prevalence of obesity would more than doubled, from the current 6% (based on BMI of 30) to 16.4% (based on BMI of 27). Using these cut-off values for screening would enable the detection of high-risk groups for further investigations and intervention where necessary.

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