**Original Article**

# Can dietary factors explain differences in serum cholesterol profiles among different ethnic groups (Chinese, Malays and Indians) in Singapore?

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In Singapore, there exists differences in risk factors for coronary heart disease among the three main ethnic groups: Chinese, Malays and Indians. This study aimed to investigate if differences in dietary intakes of fat, types of fat, cholesterol, fruits, vegetables and grain foods could explain the differences in serum cholesterol levels between the ethnic groups. A total of 2408 adult subjects (61.0% Chinese, 21.4% Malays and 17.6% Indians) were selected systematically from the subjects who took part in the National Health Survey in 1998. The design of the study was based on a cross-sectional study. A food frequency questionnaire was used to assess intakes of energy, total fat, saturated fat, polyunsaturated fat, monounsaturated fat, cholesterol, fruits, vegetables and cereal-based foods. The Hegsted score was calculated. Serum total cholesterol, low density lipoprotein cholesterol, high density lipoprotein cholesterol were analysed and the ratio of total cholesterol to high density lipoprotein cholesterol was computed. The results showed that on a group level (six sex–ethnic groups), Hegsted score, dietary intakes of fat, saturated fat, cholesterol, vegetables and grain foods were found to be correlated to serum cholesterol levels. However, selected dietary factors did not explain the differences in serum cholesterol levels between ethnic groups when multivariate regression analysis was performed, with adjustment for age, body mass index, waist-hip ratio, cigarette smoking, occupation, education level and physical activity level. This cross-sectional study shows that while selected dietary factors are correlated to serum cholesterol at a group level, they do not explain the differences in serum cholesterol levels between ethnic groups independently of age, obesity, occupation, educational level and other lifestyle risk factors.

**Key words: Chinese, dietary factors, ethnic, Indians, Malays, serum cholesterol, Singapore.**

## Introduction

The mortality from cardiovascular disease in Singapore is high, with age-standardised deaths from ischaemic heart disease at 100 per 100 000 population.[1] This is comparable to developed countries such as Australia (97 per 100 000) and United States (125 per 100 000), but higher than in other parts of Asia with similar economic development, such as Japan (22 per 100 000) and Hong Kong (40 per 100 000).[1]

Singapore is a multi-ethnic society with a population consisting of three main ethnic groups, Chinese (77%), Malays (14%) and Indians (7.6%). From the National Health Survey in Singapore conducted in 1992 and 1998 and studies by Hughes, it is apparent that cardiovascular risk factors and mortality differ in the three major ethnic groups in Singapore.[2–7] Such risk factors include obesity, abdominal fat distribution, elevated blood pressure, abnormal blood lipids, elevated blood glucose and insulin. The prevalence of obesity is highest among the Malays, followed by the Indians and Chinese, while Indians have the highest prevalence of abdominal fatness. Malays have the highest prevalence of hypertension and hypercholesterolemia. In contrast, Indians have the highest prevalence of diabetes mellitus and are more likely to have hyperinsulinaemia. Overall, Indians have the highest incidence of acute myocardial infarcts followed by Malays and Chinese.[4] Among the three ethnic groups, there are also differences in lifestyle risk factors, such as smoking, alcohol consumption and physical activity levels. Most of the smokers (classified as having at least one cigarette per day) in Singapore are males, with the proportion of Malay smokers being 1.5 times more than the Chinese and Indians. Only 2.6% of adult Singaporeans reported to be regular drinkers of alcoholic beverages (≥4 days a week), with Chinese being the group that is more likely to be regular drinkers. The proportion of adults who reported to have regular physical activity (exercised ≥ 20 minutes for ≥3 days a week) is highest for the Indians.[3]

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The causes of coronary heart disease are multifactorial, including lifestyle related risk factors, genetic factors, environmental factors and inadequate or ineffective medical care.[8] Among the lifestyle related risk factors are diet, smoking and physical activity. The decline in deaths from coronary heart disease in the United States and other developed countries has been partly attributed to lifestyle changes.[9–11] One of the main predictors of coronary heart disease mortality is serum cholesterol which is known to be strongly related to coronary heart disease mortality both at population and individual levels.[12] Elevated total serum cholesterol (TC), particularly low-density lipoprotein cholesterol (LDL) and low levels of high-density lipoprotein cholesterol (HDL) are known risk factors for coronary heart disease.[13] The relationship between serum cholesterol and risk for coronary heart disease is strong and continuous, with risk increasing progressively with increases in total serum cholesterol from 3.9 mmol/L onwards.[14,15]

Cross-country comparisons of data observe that elevated serum cholesterol is generally observed with national diets rich in animal products and refined cereals rather than more 'plant-based' diets of developing countries.[14,16] Keys reported in a comparative study of seven countries that there are strong associations between fat intake (particularly saturated fat) and elevated serum cholesterol levels and heart disease. The hypercholesterolaemic effect of saturated fat is found to be enhanced by a diet high in cholesterol, while consumption of fruit and vegetables is inversely correlated to mortality from heart disease.[17,18] This can have been affected via anti-oxidants abundant in fruit and vegetables. Another food group found to be beneficial for heart health is grains, most probably through dietary fibre and a combination of other non-nutrients such as phytoestrogens (for example, lignans) and anti-oxidants (for example, vitamin E).[18,19]

Thus a diet that is high in total fat, saturated fat and cholesterol, but low in unsaturated fats, fruit and vegetables has an adverse effect on serum cholesterol.[14,16,20] Differences in dietary intakes might explain part of the variation in levels of risk factors among the different ethnic groups in Singapore.

The aim of this study was to determine the intakes of energy, total fat, types of fat, cholesterol, fruit, vegetable and cereal-based foods among three ethnic groups in Singapore and examine if the differences in serum cholesterol levels between ethnic groups could be explained by intake patterns after correction for known confounders (age, body mass index (BMI), waist-to-hip ratio, cigarette smoking, physical activity pattern, occupation and educational level).

## Subjects and methods

The study was conducted as part of the National Health Survey in 1998 (NHS98).[3] During the NHS98, the population selection was done through a multistaged sampling process. This process has been previously described.[3] Malays and Indians were oversampled to ensure sufficient sample sizes in these two ethnic groups. The survey yielded a response rate of 64.5% and the ethnic composition of the final sample ($n$ = 4723) was 64% Chinese, 21% Malays and 15% Indians. There were no differences in the characteristics of the nonrespondents and the subjects in the final sample. A subsample of 2408 subjects were selected systematically (1 in 2) on site to participate in the dietary survey. This sample was similar in characteristics with the subjects who took part in the NHS98, except for a slight under representation of Chinese (61.0%) and overrepresentation of Indians (17.6%). In the analysis, weight values were applied, where appropriate, to reflect the actual ethnic, age and sex distribution of the general Singaporean adult population.

All survey field workers were briefed extensively on the survey methodology and underwent rigorous training in the survey procedures assigned to them. A one-day trial of the survey was conducted to hone the field worker's skills and familiarise them with the survey procedure.

The Ministry of Health and the National Medical Research Council in Singapore approved the study protocol and all subjects gave their written consent on the actual survey day.

An interview-administered questionnaire was used to obtain information about occupation, educational level, smoking habits (number of cigarettes smoked per day) and physical activity (number of sessions of aerobic activity engaged in per week).

Weight was measured in light indoor clothes without shoes using calibrated digital scales (SECA, Hamburg, Germany) with an accuracy of 0.1 kg. Body height was measured with the Frankfurt plane horizontal, to the nearest 0.1 cm without shoes using wall-mounted stadiometers. From weight and height the BMI (weight in kg/height in $m^2$) was calculated. Waist was measured to the nearest 0.1 cm, midway between the lower rib margin and the iliac-crest at the end of a gentle expiration. Measurements were taken directly on the skin. Hip circumference was measured to the nearest 0.1 cm over the great trochanters directly over the underwear.[21] The waist-to-hip ratio (WHR) was calculated.

Overnight fasting blood samples were taken and plasma was separated and analysed on the same day. The TC was determined using an enzymatic method with a commercially available test kit (Boehringer Mannheim GmbH, test kit 1489704, Mannheim, Germany). The HDL cholesterol was determined by the homogeneous enzymatic test (Boehringer Mannheim GmbH, test kit 1731203, Mannheim, Germany) and LDL cholesterol was measured with the homogeneous turbidimetric method (Boehringer Mannheim GmbH, test kit 1730843, Mannheim, Germany). The TC to HDL ratio (TCHDL) was calculated.

To assess the 'usual' dietary intakes of the subjects over the past 1 month, a food frequency questionnaire (FFQ) was used. This FFQ was developed for the purpose of assessing intakes of energy, total fat, saturated fat, polyunsaturated fat, monounsaturated fat and cholesterol among adult Singaporeans.[22] Included in this questionnaire was a section for obtaining details on intakes of food groups, particularly fruit and vegetables. It comprised a food list of 159 individual food items grouped into 23 main food types and 25 subfood types and was found to be an adequate tool to classify individuals into quintiles of intake.[22] Nutritionists and nutrition technologists underwent two days of training to standardise interviewing techniques. A further two days were spent in training of data handling.

The FFQ was administered in the language (either in English, Mandarin, Malay or Tamil) that the subject was most comfortable with, with use of interpreters where necessary. The subject was asked to recall usual intakes of the foods on the food list over the past 1 month. The usual serving sizes of each food item in common household measures (for example, rice bowl, soup spoon, cups) were included in the list. Columns were provided to enable subjects to report intake as frequency per day, per week or per month. To aid the recall, life size food models, food pictures and household utensils were used. Subjects could choose to report the intake in the preferred serving sizes (this was later coded as fractions of the standard serving portions). Foods consumed less than once a month were not recorded. The food composition database residing in the Department of Nutrition in Singapore was used for computation of intakes of energy (kcal), protein (g), fat (g), saturated fat (g), polyunsaturated fat (g), monounsaturated fat (g) and cholesterol (mg). Per cent of energy as total fat (%fat), saturated fat (%sfa), polyunsaturated fat (%pufa), monounsaturated fat (%mufa) were calculated. Cholesterol intake was also expressed as cholesterol (mg per 1000 kcal). Quintiles of intakes were computed for these nutrients and food groups (servings of fruit, vegetables, rice and alternatives). Rice and alternatives (rice group) comprise cereal-based foods such as all varieties of rice, noodles, breads and grain products. The Hegsted score was also calculated according to the formula:[23]

Hegsted score = 2.16%sfa – 1.65%pufa + 0.0677cholesterol – 0.53.

The higher the Hegsted score, the greater the cholesterol-raising effect of the diet. This score has been chosen as it takes into account lipid-related components of the diet known to affect TC. The composite score was used in the multivariate analysis in place of its components, %sfa, %pufa and cholesterol intakes. The Hegsted score could be used subsequently to predict changes in serum cholesterol levels when longitudinal data on changes in %sfa, %pufa and cholesterol intakes are available.

As the intakes of fruit, vegetables, rice group and Hegsted score were skewed to the right, they were log-transformed and used in statistical analysis. Log transformation was also performed for TC, LDL, HDL and TCHDL as these were also positively skewed.

Statistical analyses were performed using SPSS 8.01 (SPSS, Chicago, USA).[24] Values are given as mean ± SD. Analysis of (co)variance was used to test differences in levels of serum cholesterol and dietary intakes between ethnic groups with age as the covariate. Correlations are Pearson's partial correlation coefficients with correction for age. Multivariate analysis of variance was conducted to analyse the difference in levels of serum cholesterol (TC, LDL, HDL and TCHDL) between ethnic groups as contributed by the different covariates (such as age, BMI, WHR, educational level, occupation, lifestyle factors and dietary factors). Relative risk (odds ratio) of elevated serum cholesterol levels between quintiles of dietary intakes was calculated using logistic regression with adjustment for age, ethnicity, occupational status, educational level, number of cigarettes smoked, BMI, WHR, physical activity levels. Unless otherwise specified, a significance level of 0.05 was used.

## Results

Table 1 shows some of the characteristics of the study population. There were no age differences between the ethnic groups, for both females and males. Among the women, Chinese have the lowest body weight and are taller, with the lowest BMI. They also have the smallest waist circumference (waist) and WHR. Indian women have the largest waist and WHR. For men, Malays were the shortest and have the highest BMI, while Indians have the largest waist and WHR. Chinese men have the lowest BMI.

In Table 2 the dietary intakes of total energy, total fat, protein, %fat, %sfa, %pufa, %mufa and cholesterol are presented along with intakes of fruits, vegetables and rice group. The computed Hegsted score is also found in Table 2. Among the women, Indians have the highest intakes of energy, %fat, %pufa, vegetables and rice group, with the lowest %mufa in their diet. Chinese women have the lowest intake of %fat, %sfa and rice. Malay women have the lowest vegetable intakes. There is no difference in intakes of protein and fruits. For men, there is no difference in dietary intakes of energy, total fat, protein, vegetables and rice group among the ethnic groups. Chinese men have the lowest %fat and %sfa, while Malay men have the highest %fat and lowest %pufa. Indian men consumed the highest %pufa and most servings of fruit. For both men and women, Indians have the lowest cholesterol intakes, both in absolute amounts and when expressed as per 1000 kcal and also the lowest Hegsted score.

When the mean intake of each of the six sex–ethnic groups was correlated with the mean levels of serum cholesterol, Pearson correlation coefficients for the six groups are positive between TC and Hegsted score ($r = 0.77$), %sfa ($r = 0.61$), rice group ($r = 0.60$) and negative between TC and vegetables ($r = -0.82$). The TCHDL is positively correlated with %sfa ($r = 0.86$), Hegsted score ($r = 0.67$), rice group ($r = 0.70$) and %fat ($r = 0.60$). Strong negative correlations are found between HDL and %sfa ($r = -0.85$), %fat ($r = -0.72$) and rice group ($r = -0.63$).

Figure 1 compares the percentiles of intakes of selected food components (%fat, %sfa, servings of fruit plus vegetables and rice). Among the women, Chinese have lowest values for all percentiles of %fat and %sfa. For %fat, Malay and Indian women have similar values up to 50th percentile. At the higher percentiles, Indians have higher values, indicating that there are more Indian women in the higher range of intake compared to Malays. Both Indian and Malay women have similar values of %sfa for all percentiles. For men, Chinese have lowest values, while Malays have highest for all percentiles of %fat and %sat. More Indian women tend to have higher intakes of fruit, vegetables, rice and rice alternatives when compared to Malay and Chinese women. Chinese men have lower intakes of fruit and vegetables and higher intakes of rice and rice alternatives throughout the range of intakes.

Table 3 presents the levels of TC, LDL, HDL and ratio of TCHDL levels for the different groups. Chinese (men and women) have the lowest TC, LDL and TCHDL levels, while Malay men and women have the highest TC levels.

Relative risks (odds ratio) of having elevated TC (≥6.2 mmol/L), LDL (≥4.1 mmol/L), TCHDL (≥4.4) or low HDL (<0.9 mmol/L) were computed for quintiles of intake of energy, %fat, %sfa, %pufa, %mufa, cholesterol, rice, fruit and vegetables, with correction for age, BMI and WHR.[13] There is no significant difference in relative risks for increasing quintiles of intake for all risk factors. When comparing the dietary intake, there is no significant difference in the

**Table 1.** Distribution of some characteristics of sample population

| | Chinese | | Malays | | Indians | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Females (*n*) | 806 | | 268 | | 224 | | 1298 | |
| Age (years) | 38.5 | 12.2 | 37.8 | 12.2 | 38.7 | 11.2 | 38.4 | 12.0 |
| Weight (kg) | 54.4[a] | 8.8 | 62.5[b] | 12.8 | 61.9[b] | 11.7 | 57.4 | 10.9 |
| Height (cm) | 157.1[a] | 5.5 | 154.3[b] | 5.9 | 156.1[c] | 6.0 | 156.4 | 5.8 |
| BMI (kg/m$^2$) | 22.1[a] | 3.5 | 26.3[b] | 5.1 | 25.5[b] | 4.9 | 23.5 | 4.5 |
| Waist (cm) | 73.2[a] | 8.3 | 78.9[b] | 10.6 | 81.2[c] | 10.8 | 75.8 | 9.8 |
| WHR | 0.78[a] | 0.05 | 0.80[b] | 0.10 | 0.81[b] | 0.07 | 0.80 | 0.07 |
| Males (*n*) | 663 | | 247 | | 200 | | 1110 | |
| Age (years) | 39.2 | 12.6 | 38.7 | 12.4 | 40.7 | 11.1 | 39.3 | 12.3 |
| Weight (kg) | 67.7 | 11.9 | 69.5 | 12.0 | 69.7 | 11.9 | 68.5 | 12.0 |
| Height (cm) | 169.3[a] | 6.5 | 166.6[b] | 6.3 | 169.8[a] | 6.5 | 168.8 | 6.6 |
| BMI (kg/m$^2$) | 23.6[a] | 3.8 | 25.0[b] | 4.0 | 24.2 | 3.8 | 24.0 | 3.9 |
| Waist (cm) | 84.4[a] | 9.9 | 85.9 | 10.6 | 88.2[b] | 10.2 | 85.4 | 10.2 |
| WHR | 0.88[a] | 0.06 | 0.87[a] | 0.06 | 0.90[b] | 0.06 | 0.88 | 0.06 |

[a,b,c] For each row, different alphabets indicate significant difference between ethnic groups. BMI, body mass index; WHR, waist-to-hip ratio.

**Table 2.** Distribution of selected dietary intakes by gender and ethnic groups

| | Chinese Mean ± SD | Malays Mean ± SD | Indians Mean ± SD | All Mean ± SD |
|---|---|---|---|---|
| Females | | | | |
| Energy (kcal) | 1812[a] ± 606 | 1902[a] ± 641 | 2081[b] ± 710 | 1879 ± 640 |
| Total fat (g) | 55.2[a] ± 24.5 | 60.5[b] ± 26.4 | 66.3[c] ± 28.9 | 58.2 ± 26.0 |
| % fat | 26.8[a] ± 5.4 | 27.9[b] ± 5.4 | 28.2[c] ± 5.4 | 27.3 ± 5.4 |
| % sfa | 10.1[a] ± 2.5 | 11.6[b] ± 2.9 | 11.5[b] ± 2.9 | 10.7 ± 2.8 |
| % mufa | 9.3[a] ± 2.3 | 9.1[a] ± 2.3 | 8.0[b] ± 2.3 | 9.0 ± 2.4 |
| % pufa | 5.6[a] ± 2.2 | 5.1[b] ± 2.2 | 6.2[c] ± 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[a] ± 114 | 236[a] ± 122 | 197[b] ± 115 | 220 ± 116 |
| Chol (mg)/1000 kcal | 120[a] ± 42 | 121[a] ± 41 | 92[b] ± 38 | 116 ± 43 |
| Hegsted score | 14.7[a] ± 7.7 | 15.6[a] ± 8.3 | 12.9[b] ± 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[a] ± 0.79 | 1.22[a] ± 0.92 | 1.42[b] ± 0.65 | 1.29 ± 0.79 |
| Rice group (servings) | 5.42[a] ± 1.88 | 5.48 ± 2.27 | 5.84[b] ± 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[a] ± 5.4 | 27.6[b] ± 6.4 | 27.2 ± 5.4 | 26.8 ± 5.6 |
| % sfa | 10.4[a] ± 2.5 | 11.8[b] ± 3.2 | 11.3[b] ± 3.0 | 10.9 ± 2.8 |
| % mufa | 9.2[a] ± 2.3 | 9.0[a] ± 2.6 | 8.1[b] ± 2.2 | 9.0 ± 2.4 |
| % pufa | 4.9[a] ± 1.7 | 4.4[b] ± 1.7 | 5.5[c] ± 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[a] ± 148 | 295[a] ± 164 | 244[b] ± 141 | 285 ± 151 |
| Chol (mg)/1000 kcal | 124[a] ± 39 | 123[a] ± 43 | 103[b] ± 45 | 120 ± 42 |
| Hegsted score | 19.5[a] ± 10.1 | 19.6[a] ± 11.1 | 16.2[b] ± 9.5 | 18.9 ± 10.3 |
| Fruits (servings) | 1.32[a] ± 1.01 | 1.26 ± 1.30 | 1.56[b] ± 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 group (servings) | 7.23 ± 2.39 | 7.08 ± 2.55 | 6.97 ± 2.89 | 7.15 ± 2.54 |

[a,b,c] 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 monounsaturated fatty acids; % pufa, % energy as polyunsaturated fatty acids; Chol, cholesterol.

intake of the above-named dietary factors between subjects with elevated risks and those with normal levels of TC, LDL, HDL and TCHDL (tested using analysis of variance and correcting for age). There is also no difference in Hegsted score between those with elevated TC and those with normal TC.

In Table 4, the amount of variance ($r^2$) in serum cholesterol levels between ethnic groups that could be explained by the different variables are presented. It can be seen that the factors, in Model 1 (age, BMI and WHR), account for most of the differences between ethnic groups, ranging from 22.5% (for TC) to 29.8% (for LDL) in women, and from 17.9% (TC) to 33.7% (TCHDL) in men. In Model 2, educational level, occupational status, activity level and smoking are entered into the regression analysis, resulting in slight

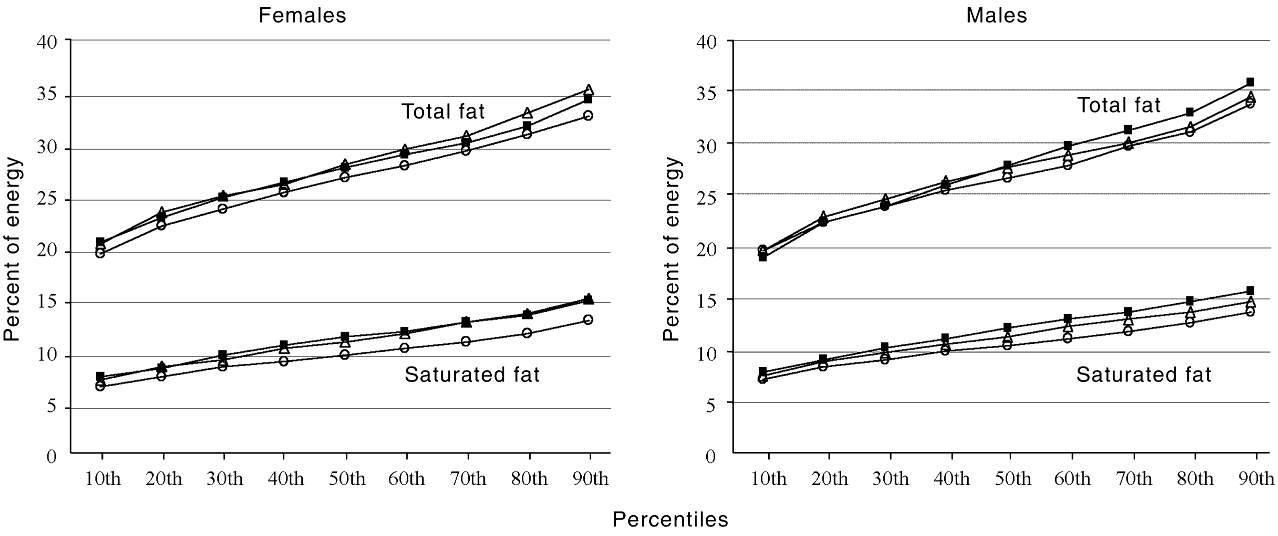


**Figure 1.** Distribution of subjects by percentiles of fat and saturated fat intakes (per cent of energy) by sex and ethnic group. (○), Chinese; (■), Malays; (△), Indians.

**Table 3.** Distribution of TC, LDL, HDL, TC/HDL, by sex and ethnic group

| | Chinese Mean ± SD | Malays Mean ± SD | Indians Mean ± SD | All Mean ± SD |
|---|---|---|---|---|
| Females | | | | |
| TC (mmol/L) | 5.4[a] ± 1.1 | 5.7[b] ± 1.1 | 5.3[a] ± 1.0 | 5.4 ± 1.1 |
| LDL (mmol/L) | 3.3[a] ± 1.0 | 3.7[b] ± 1.1 | 3.5[b] ± 0.9 | 3.4 ± 1.0 |
| HDL (mmol/L) | 1.7[a] ± 0.4 | 1.6[b] ± 0.3 | 1.4[b] ± 0.3 | 1.6 ± 0.4 |
| TC/HDL | 3.3[a] ± 1.0 | 3.8[b] ± 1.1 | 4.0[b] ± 1.1 | 3.5 ± 1.1 |
| Males | | | | |
| TC (mmol/L) | 5.5[a] ± 1.0 | 5.9[b] ± 1.2 | 5.7 ± 1.0 | 5.6 ± 1.1 |
| LDL (mmol/L) | 3.5[a] ± 0.9 | 3.9[b] ± 1.1 | 3.8[b] ± 1.0 | 3.7 ± 1.0 |
| HDL (mmol/L) | 1.4[a] ± 0.3 | 1.3[b] ± 0.3 | 1.2[b] ± 0.3 | 1.3 ± 0.3 |
| TC/HDL | 4.2[a] ± 1.4 | 4.9[b] ± 1.6 | 4.9[b] ± 1.4 | 4.5 ± 1.5 |

[a,b,c] For each row, different alphabets indicate significant difference between ethnic groups using analysis of covariance with age as covariate. TC, total serum cholesterol; LDL, low-density lipoprotein cholesterol; HDL, high-density lipoprotein cholesterol; TC/HDL, ratio of TC to HDL.

**Table 4.** Variance in blood lipid levels between ethnic groups (Chinese, Malays, Indians) accounted for by different parameters, by sex

| | Model 1 variables[a] $r^2$* | Model 2 variables[b] $r^2$* | Model 3 variables[c] $r^2$* |
|---|---|---|---|
| Females | | | |
| TC (mmol/L) | 0.225 | 0.226 | 0.228 |
| LDL (mmol/L) | 0.257 | 0.258 | 0.262 |
| HDL (mmol/L) | 0.244 | 0.244 | 0.240 |
| TC/HDL | 0.298 | 0.299 | 0.299 |
| Males | | | |
| TC (mmol/L) | 0.179 | 0.186 | 0.194 |
| LDL (mmol/L) | 0.227 | 0.233 | 0.238 |
| HDL (mmol/L) | 0.222 | 0.238 | 0.241 |
| TC/HDL | 0.337 | 0.356 | 0.360 |

TC, total serum cholesterol (log); LDL, low-density lipoprotein cholesterol (log); HDL, high-density lipoprotein cholesterol (log); TC/HDL, ratio of TC to HDL (log). [a]Age; body mass index; waist-hip ratio. [b]Age; body mass index; waist-hip ratio; educational level; activity level; smoking status. [c]Age; body mass index; waist-hip ratio; educational level; activity level; smoking status; dietary intake of energy; per cent energy as fat, per cent energy as monounsaturated fatty acids, Hegsted score (log); servings of fruit (log), vegetables (log) and rice group (log). *$r^2$, amount of variance as explained by the respective groups of variables as they are entered as covariates in the analysis of covariance, when comparing levels of serum cholesterol between ethnic groups.

increases in $r^2$. The further addition of dietary factors to the other variables (Model 3) accounts for only small increases in $r^2$ of about 1% or less.

## Discussion

In this study it was found that generally the diet of Singaporeans is low in fruits and vegetables. The amount of servings of rice and alternatives fell within the 5–7 servings recommended, but in a previous report it was shown that only 0.11 servings of these were made of wholegrains.[25,26] The absolute intakes of total fat, saturated fat and cholesterol are lower than that for US, Finland, the Netherlands and Italy, but higher than for Japan.[27] When expressed as per cent of energy intake, the mean %fat intake was within the recommended limit of < 30% of energy intake, but the %sfa was higher than the recommended limit of 10% of energy intake for all sex–ethnic groups.[14,15] Such a dietary profile (low in fruits, vegetables wholegrain and high %sfa) has been found to correspond to a high-risk for coronary heart disease on a population level.[14,18,28]

Indeed, when correlating the mean intakes of these six sex–ethnic groups with their respective serum cholesterol levels, the correlations are consistent with reports from past scientific reviews regarding the effects of fat and types of fat on serum cholesterol levels. The unexpected adverse correlation between the rice group and serum cholesterol levels could be because the type of grain-based foods consumed in Singapore are mainly of the refined type (with wholegrains making up less than 0.11 serving per day of the average adult diet) and that rice and noodles, the staple food of Singaporeans, are often consumed prepared with high fat and high saturated fat ingredients.[26] Rice flavoured with high fat ingredients and fried noodles contribute to almost 14% of the total fat intake and 15% of total saturated fat intake of Singaporeans.[26] This makes them the major contributors compared to other food groups.

However, on the individual level, as shown in the present study, the selected dietary factors could not account for the differences in serum cholesterol levels between the different ethnic groups when possible confounders were taken into account. The same dietary methodology was employed for all three ethnic groups and measured 'usual' consumption over the same reference period of 1 month. The food composition tables used comprise local foods analysed in the same laboratory in the 3 years prior to the conduct of the present study. Thus, it is unlikely that inconsistent methodology or differences in food composition tables could have affected the results as was the case in some studies comparing population groups.[28] The FFQ used to assess dietary intakes was found during the validation study to slightly overestimate intakes of total fat (by 3%), saturated fat (by 2%), monounsaturated fat (by 1%) when compared to the referent method. Intake of polyunsaturated fat was overestimated by 11% and that for cholesterol was underestimated by 17%.[22] Such variations are within the limits (between 1% and 55%) reported by other studies.[29–33] However, on a group level, the questionnaire was found to be adequate for classifying individuals into quintiles of intake for correlation purposes.[22]

The results from this study show that on a group level, %fat, %sfa, Hegsted score and intakes of vegetables and rice group are correlated with serum cholesterol levels. However, at the individual level, these dietary factors do not explain the differences in serum cholesterol levels between the ethnic groups. 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. While the mean differences for the intakes are found to be statistically different between some groups, the actual differences are small and the large sample sizes could have contributed to the statistical significance. The distribution of intakes as seen in Fig 1 show that there are only slight differences throughout the range of intakes. Another reason is that determinants of disease at the individual level are not necessarily the same as those in the population level.[34] Correlations between factors and disease (risks) found in cross-country studies could be confounded by a multitude of other factors, including genetic, cultural, environmental and lifestyle factors. 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. For example, not all saturated fats are equally cholesterolaemic and the saturated fat effect is related to the dietary cholesterol load and lipoprotein metabolism (or lipoprotein setpoint) of the individual.[28,35] More recent reports also suggest that high intakes of fruits and vegetables can modulate the effects of dietary fat.[36]

Certainly, a major drawback of the present study is the cross-sectional nature. As 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 once every 5 years. Such a prospective study can then examine the influences of changes in dietary and other lifestyle factors on disease risks and provides better evidence on how these could be addressed to lower the individual and population risks.

In summary, the current study shows that on a population basis, dietary factors (total fat, saturated fat, Hegsted score, fruits, vegetables, rice group) are correlated to serum cholesterol levels. However, during individual-based analysis, the relative risks for having elevated TC, LDL, TCHDL and low HDL are not found to be increased with the quintiles of intakes of these dietary factors. The intakes were also not different between those with normal serum cholesterol levels and those with abnormal levels. Dietary factors are not responsible for the differences in serum cholesterol levels among three ethnic groups in Singapore. In view of the shortcomings of a cross-sectional study, a prospective study is recommended to further investigate the relationship between changes in diet (and other lifestyle risk factors) and coronary risks among the different ethnic groups.

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