Summary

The dietary intake of cholesterol, phytosterol and PUFA in Japanese was investigated to obtain information on dietary parameters related to coronary artery disease. Three daily menus for both 1957 and 1982 were prepared based on the daily per capita consumption of foods and nutrient intakes from national surveys. From 1957 to 1982, the average daily intake of cholesterol rose 2.1-fold from 183 to 376 mg while that of phytosterol remained at about 373 mg. Daily intakes of total fatty acid (19.2 g), PUFA (7.3 g), MUFA (5.8 g) and SFA (6.1 g) in 1957 increased in 1982 to 48.7 g, 11.9 g, 19.5 g and 17.3 g, respectively. The ratio of PUFA/SFA decreased to 56% from 1.23 in 1957 to 0.69 in 1982 and the PUFA/MUFA ratio also decreased to 48%. The PUFA/cholesterol ratio was lower in 1982 (31.8) than in 1957 (42.6), and the decrease in the phytosterol/cholesterol ratio to 46% was greater than that in the PUFA/cholesterol ratio (which only fell to 75% of the 1957 value). Thus, comparison of the 1982 and 1957 intakes indicated the increase in risk factors, cholesterol and SFA intake, and the decrease in the ratio of PUFA/SFA in the Japanese population during the past few decades.

Key Words: intake of sterol and fatty acid, cholesterol, phytosterol, PUFA, PUFA/SFA, PUFA/MUFA, PUFA/cholesterol, phytosterol/cholesterol
the diet has a cholesterol lowering effect (7, 8). On the other hand, on a low-fat diet, no effects of the PUFA/SFA ratio on the serum cholesterol level have been reported (9). It is known that the absorption of dietary cholesterol is interfered with by phytosterol (10, 11). Thus, although the mechanisms responsible for these hypocholesterolemic effects have not yet been defined, dietary factors such as cholesterol, phytosterol and fatty acid must influence the serum cholesterol level.

The incidence of coronary artery disease has increased about threefold with the increase in serum cholesterol in the Japanese population during the past few decades and this seems to be due to the changing Japanese dietary habits, with the increased intake of meats, eggs, and dairy products and decreased intake of cereals and potatoes. If the changes in both the actual and relative amounts of dietary constituents influence the incidence of coronary artery disease, then one would expect to find significant differences in dietary patterns of the past and present. To determine the dietary parameters related to coronary artery disease, we examined the daily dietary intake amounts and relative ratios of cholesterol, phytosterol, PUFA, MUFA and SFA of composite representative diets for 1957 and 1982 in Japan to compare the intakes in those years.

**EXPERIMENTAL PROCEDURE**

*Composite diet.* Three daily menus for 1957 and 1982 were prepared based on the daily per capita consumption of foods and nutrient intakes based on national surveys conducted in Japan in 1957 and 1982 (Tables 1 and 2). The nutrient compositions for 1957 and 1982 were calculated from The Standard Tables of Food Composition in Japan (2nd and 4th edition, respectively). All food items were purchased on the domestic market and, if necessary, powdered. Foodstuffs comprising a day's diet were weighed, mixed with a mixer and stored at -40°C until analysis.

*Analysis for sterols and fatty acid composition of the composite diet.* Lipids were extracted from each homogenized diet (20 g) by three extractions with 100 ml chloroform–methanol (2:1) followed by two extractions with 100 ml hot benzene. Saponification of lipids and fractionation of sterols and fatty acids were done as reported previously (12). Fatty acid methyl esters prepared by using BF3-methanol and sterols were analyzed by gas-liquid chromatography (Model 163, Hitachi Ltd.) and equipped with a flame ionization detector as follows. To analyze sterols, a 1-m glass column (3 mm i.d.) packed with 3% OV-1 coated on 100–120 mesh Gaschrom Q (Gasukuro Kogyo) was used at 240°C under a nitrogen flow rate of 40 ml/min. Fatty acid methyl esters were separated on a 3-m glass column (3 mm i.d.) and packed with 5% Silar 5CP coated on 80–100 mesh Uniport H.P. (Gasukuro Kogyo). The temperature was programed to increase from 210°C to 250°C at 3°C per min and the carrier gas (nitrogen) flow rate was 20 ml/min. Sterols and fatty acids were identified by comparing retention time with those of authentic standards (Gasukuro Kogyo, NU-CHEK-PREP Inc., and Serdary Research Laboratories J. Nutr. Sci. Vitaminol.)
Table 1. Compositions of composite diets representing the daily per capita consumption in Japan in 1957 and 1982.

| Food group                | 1957 (g/day) | 1982 (g/day) |
|---------------------------|--------------|--------------|
|                           | National survey | Composite diet | National survey | Composite diet |
|                           |               | a            |               | a            |
| Cereals                   | 458          | 453 ± 4      | 316           | 308 ± 8      |
| Potatoes and starches     | 78           | 80 ± 11      | 61            | 61 ± 1       |
| Sugars and sweetenings    | 10           | 10 ± 1       | 12            | 14 ± 2       |
| Fats and oils             | 5            | 5 ± 0        | 18            | 24 ± 1       |
| Pulses                    | 70           | 68 ± 12      | 67            | 64 ± 14      |
| Vegetables (Colored)      | 50           | 51 ± 7       | 59            | 58 ± 3       |
| (Other)                   | 171          | 170 ± 5      | 201           | 202 ± 15     |
| Fruits                    | 64           | 67 ± 5       | 160           | 165 ± 11     |
| Algae                     | 5            | 5 ± 2        | 5             | 5 ± 2        |
| Fishes and shellfishes    | 76           | 85 ± 0       | 90            | 90 ± 0       |
| Meats                     | 15           | 16 ± 1       | 71            | 70 ± 0       |
| Eggs                      | 13           | 11 ± 1       | 40            | 40 ± 0       |
| Milk and dairy products   | 18           | 27 ± 16      | 124           | 123 ± 9      |

* Each value represents the mean ± SD for three composite diets prepared from different food stuffs.

Table 2. Amounts of nutrients in composite diets representing the daily per capita nutrient intake in Japan in 1957 and 1982.

| Component                      | 1957 | 1982 |
|--------------------------------|------|------|
|                               | National survey | Composite diet | National survey | Composite diet |
|                               |               | a            |               | a            |
| Total energy (kcal)           | 2130           | 2145 ± 39    | 2136           | 2155 ± 47    |
| Total protein (g)             | 71.2           | 71.4 ± 6.6   | 79.6           | 83.4 ± 3.3   |
| (% cal from protein)          | (13.4)         | (13.1)       | (15.4)         | (15.3)       |
| Animal protein (g)            | 24.7           | 22.9 ± 4.5   | 40.0           | 39.5 ± 0.5   |
| (% protein from animal)       | (34.7)         | (32.1)       | (50.3)         | (47.4)       |
| Total Fat (g)                 | 22.4           | 22.4 ± 1.7   | 58.0           | 57.8 ± 3.2   |
| (% cal from fat)              | (9.4)          | (9.2)        | (25.3)         | (23.9)       |
| Total carbohydrates (g)       | 411            | 425 ± 3      | 306            | 331 ± 13     |
| (% cal from carbohydrates)    | (77.2)         | (77.7)       | (59.3)         | (60.8)       |

* Calculated from The Standard Tables of Food Composition in Japan. Each value represents the mean ± SD for three composite diets.

Inc.). The contents of sterols and fatty acids were corrected on the basis of the recovery of the added internal standard of 5α-cholestane (Sigma) and heptadecanoic acid (17:0) (Sigma), respectively. Fatty acid groups, SFA, MUFA and PUFA, were...
classified based on the information given in the dietary fats and oils in human nutrition of the Food and Agriculture Organization of the United Nations (13).

RESULTS AND DISCUSSION

Daily intake of PUFA, MUFA and SFA and the ratios of the fatty acid groups

The fatty acid compositions of the composite diets and the comparisons of the fatty acid groups are summarized in Tables 3 and 4, respectively. The amounts of total fatty acid in three daily composite diets which averaged 19.2 g in 1957 increased 2.53-fold in 1982 (48.7 g/day) (Table 3). Comparison of the amounts of the fatty acid groups in 1982 with those in 1957 showed that the daily intake of SFA increased 2.85-fold and MUFA and PUFA also increased 3.34- and 1.62-fold, respectively (Table 4). The rate of increase in the percentage of MUFA from 30.3% to 40.0% was more remarkable than that of SFA from 31.5% to 35.5% (Table 4). On the other hand, the percentage of PUFA in total fatty acid decreased from 38.2% in 1957 to 24.5% in 1982, which seemed to be mainly due to the increase in the percentage of MUFA. The daily PUFA intake in 1982 (11.9 g, Table 4) agreed with the 12.12 g reported by Koga et al. (14) in 1981 for the Japanese diet, but the percentage of PUFA in 1982 (24.5%) was lower than their finding (29.3%).

Table 5 shows the values adjusted for differences in caloric intake in Denmark (15), the United States (16) and Japan (present data). The dietary PUFA Table 3. Fatty acid compositions of composite diets representing the daily per capita consumption of food in Japan in 1957 and 1982.

| Fatty acid | Composite diet (g/day)* |
|-----------|-------------------------|
|           | 1957       | 1982       |
| 14:0      | 0.66±0.29 (3.4) | 1.55±0.52 (3.2) |
| 16:0      | 3.79±0.37 (19.7) | 10.81±0.51 (22.2) |
| 16:1      | 0.44±0.02 (2.3) | 1.23±0.11 (2.5) |
| 17:0      | 0.09±0.02 (0.4) | 0.38±0.04 (0.8) |
| 17:1      | 0.07±0.05 (0.4) | 0.16±0.11 (0.3) |
| 18:0      | 1.07±0.36 (5.6) | 3.92±0.11 (8.1) |
| 18:1      | 4.76±0.60 (24.8) | 17.61±1.11 (36.2) |
| 18:2      | 5.13±0.06 (26.7) | 9.85±0.50 (20.3) |
| 18:3      | 0.83±0.08 (4.3) | 1.24±0.06 (2.6) |
| 20:0      | 0.33±0.18 (1.7) | 0.39±0.07 (0.8) |
| 20:1      | 0.55±0.51 (2.9) | 0.49±0.07 (1.0) |
| 20:4      | 0.05±0.01 (0.3) | 0.12±0.04 (0.2) |
| 22:0      | 0.08±0.04 (0.4) | 0.14±0.01 (0.3) |
| 20:5      | 0.04±0.69 (4.9) | 0.49±0.14 (1.0) |
| 24:0      | 0.03±0.02 (0.1) | 0.06±0.03 (0.1) |
| 22:6      | 0.40±0.25 (2.1) | 0.21±0.08 (0.4) |
| Total     | 19.22±3.28 (100) | 48.65±2.40 (100) |

*Fatty acid distribution (%) is shown in parenthesis.
level of 3.42 g/1,000 kcal in the 1957 diet with a low risk of coronary artery disease was lower than the 5.53 g for the 1982 diet, and also lower than the 4.27 g of the Denmark (1972) and the 6.45 g of the American diet (1981–1982) at high risk. The PUFA intake of 6.37 g/1,000 kcal for the low-risk diet of Eskimos was higher than the 3.42 g of the 1957 Japanese diet and was similar to the amount in the high-risk American diet (6.45 g).

The ratio of PUFA/SFA decreased from 1.23 to 0.69 in 1982 compared to the value in 1957 (Tables 4 and 5). Although there was no significant difference, the ratio PUFA/SFA in 1982 was lower than the PUFA/SFA ratio, 0.85 ± 0.18, which was calculated from the results reported by Koga et al. in 1981 for the Japanese diet (14). However the PUFA/SFA ratio in the 1982 Japanese diet was still higher than the 0.43 of the American diet and the 0.24 of the Danish diet where the coronary artery disease risk is high, and was closer to the 0.84 of Eskimos, who have a low-risk level (Table 5). As shown in Table 4, the mean PUFA/MUFA ratio in our study also decreased from 1.27 to 0.61 in 1982. Thus, the increase in intakes of SFA and MUFA over the increase in PUFA intake induced decreases in the ratios of PUFA/SFA and PUFA/MUFA in 1982, the PUFA/SFA ratio fell to 56% of the earlier value and the PUFA/MUFA ratio to 48%. From the idea that dietary factors affecting the increase of coronary artery disease in recent years have probably changed over the past few decades, our results suggested that the dietary factors contributing to an increase in coronary artery disease are an increase in SFA and a decrease in the PUFA/SFA ratio rather than the absolute amount of PUFA, and that the PUFA/MUFA ratio seems to be like a dietary parameter as the
Table 5. Comparison of the intake of PUFA and sterols per 1,000 kcal

| Country (Reference) | Year of survey | Nutrients per 1,000 kcal |
|---------------------|---------------|-------------------------|
|                     |               | PUFA (g) | Cholesterol (mg) | Phytosterol (mg) |
| Japan (present data)| 1957          | 3.42     | 85               | 174 (105<sup>a</sup>) |
|                     | 1982          | 5.53     | 175              | 173 (106<sup>a</sup>) |
| Denmark (<sup>15</sup>) | Average diet | 1972     | 4.27             |                      |
|                     | Eskimos       | 1976     | 6.37             |                      |
| USA(<sup>16</sup>)  | Average diet  | 1981–82  | 6.45             | 169                 |
| USA (intake) (<sup>19</sup>)<sup>b</sup> | non-SDA-general populn. | 1978– | 125             | 38<sup>a</sup> |
|                     | SDA-non vegetarians | 1978– | 119             | 123<sup>a</sup> |
|                     | SDA-lacto-ovo-vegetarians | 1978– | 73              | 182<sup>a</sup> |

<sup>a</sup> β-sitosterol + stigmasterol. <sup>b</sup> SDA, seventh-day adventist.

PUFA/SFA ratio in the diet.

Daily intake of cholesterol and phytosterol

The contents of cholesterol in three composite diets based on the apparent per capita consumption of foods in Japan in 1957 and 1982 are presented in Table 6. The daily amounts of cholesterol showed considerable variation from 129 to 230 mg in 1957 and from 341 to 404 mg in 1982. However the mean levels in 1982 (376 mg/day) were greater than those in 1957 (183 mg/day), showing that the cholesterol intake increased 2.06-fold during the past few decades. The level of cholesterol intake in 1982 was higher than the reported level of 220 mg/day (64–426 mg/day) in 1979(<sup>17</sup>), and 318 mg/day in 1984(<sup>18</sup>) for adults and 187 mg/day (187 ± 137 mg/day)(<sup>18</sup>) for one-year-olds for popular meals in Japan. The amount of cholesterol of 171 mg (428 mg cholesterol/100 g of egg) calculated from the 40 g per capita consumption in 1982 (Table 1), accounted for 45.5% of the 376 mg cholesterol intake in 1982. These results showed that the cholesterol intake depends on the food consumed, especially, the quantity of eggs, and varies largely from meal to meal. Therefore, the approximately twofold increment between 1957 and 1982 is probably due to an increase in the intake of eggs as well as meat and animal fat (Table 1). As the 1982 diets had 2.58-fold the total fat of the 1957 diets as shown in Table 2, the mean ratio of intake of cholesterol to total fat in the composite diet was 8.1 mg/g in 1957, which was greater than the 6.5 mg/g in 1982 (Table 5). These levels were higher than the 4.0 mg/g in the average diet in the United States(<sup>16</sup>) (Table 5). Comparison of the intake per 1,000 kcal showed that the cholesterol level of 85 mg in 1957 was lower than the 174 mg in 1982 and the 169 mg(<sup>16</sup>) and 125 mg(<sup>19</sup>) in American diets, thus resembling the diets of

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and their ratios for Denmark, the USA and Japan.

| PUFA/SFA (g/g) | PUFA/Chol (g/g) | Phyto/Chol (g/g) | Chol/Fat (mg/g) | Phyto/Fat (mg/g) |
|---------------|----------------|-----------------|----------------|-----------------|
| 1.23          | 42.7           | 2.18 (1.32*)    | 8.1            | 16.8            |
| 0.69          | 31.7           | 1.00 (0.62*)    | 6.5            | 6.5             |
| 0.24          |                |                 |                |                 |
| 0.84          |                |                 |                |                 |
| 0.43          | 39.7           |                 | 4.0            |                 |

Table 6. Amounts of sterol in composite diets representing the daily per capita consumption of food in Japan in 1957 and 1982.

| Sterol                     | Composite diet | Ratio of 1982/1957 |
|----------------------------|----------------|-------------------|
| Cholesterol (mg/day)       | 183 ± 42       | 376 ± 26          | 2.06             |
| Phytosterol (mg/day)*      | 37.6 ± 10.1    | 38.6 ± 12.0       | 1.03             |
| Brassicasterol             | (10.2)         | (10.2)            |                  |
| Campesterol                | 62.0 ± 12.8    | 53.7 ± 16.7       | 0.87             |
| (16.5)                     | (14.2)         |                  |                  |
| Stigmasterol               | 27.6 ± 16.4    | 27.9 ± 1.9        | 1.01             |
| (7.4)                      | (7.5)          |                  |                  |
| β-Sitostanol               | 198 ± 23       | 202 ± 11          | 1.02             |
| (52.9)                     | (54.2)         |                  |                  |
| Others                     | 47.9 ± 19.6    | 50.8 ± 14.5       | 1.06             |
| (13.0)                     | (13.9)         |                  |                  |
| Total                      | 373 ± 24       | 373 ± 25          | 1.00             |
| (100)                      | (100)          |                  |                  |

*Phytosterol distribution (%) is shown in parenthesis.

vegetarians (73 mg) (Table 5). As the incidence of coronary artery disease in Japan and the USA in 1978–1982 was greater than in 1957 in Japan, the quantity of cholesterol intake relative to energy intake seems to be a more important factor of this disease than the ratio of intakes of cholesterol to total fat.
As shown in Table 6, the daily intake of phytosterol in 1957 averaged 373 mg, consisting of 52.9% β-sitosterol, 16.5% campesterol, 10.2% brassicasterol and 7.4% stigmasterol. The 1982 levels of intake and composition of dietary phytosterol were similar to those of 1957, totaling 373 mg/day consisting of 54.2% β-sitosterol, 14.2% campesterol, 10.2% brassicasterol and 7.5% stigmasterol. Thus, the quantity and quality of daily phytosterol intake have not changed during the past few decades in Japan. These levels of daily phytosterol intake agreed with the 400 mg/day measured for the regular meals in Japanese University refectory (17), but were higher than the 77.9 mg/day of the American diet (19). The levels resembled those found for vegetarians (344 mg/day) (19). As shown in Table 5, the ratio of dietary phytosterol to total fat in 1982 decreased to 39% of the 1957 value from 16.8 to 6.5. Thus, although the amount of cholesterol rises together with the amount of total dietary fat, a parallel increase in phytosterol does not necessarily occur. On the other hand, the Japanese intake of two of these phytosterols, β-sitosterol and stigmasterol (for which literature data are available for comparison), relative to the caloric intakes was similar to that in 1957 (105 mg/1,000 kcal) and was greater than that of the American diet (38 mg/1,000 kcal), resembling that of the vegetarian diet (182 mg/1,000 kcal). These results may indicate that the high ratio of dietary phytosterol to total fat exerts a preferable effect on coronary artery disease than the quantity of daily phytosterol intake.

Comparison of the ratio of daily intake of PUFA and phytosterol to cholesterol

The actual levels of PUFA and cholesterol intake were both greater in 1982 than in 1957 as shown in Tables 4 and 6, while the ratio of PUFA to cholesterol intake was greater in 1957 (42.7) than in 1982 (31.7) (Table 7). However, the ratio of PUFA/cholesterol in 1957 resembled the ratio of the American diet (39.7) (16) of high risk (Table 5). These findings suggest that there are more important parameters in the relationship between PUFA intake and coronary artery disease other than the ratio of PUFA to cholesterol intake.

As shown in Table 6, cholesterol intake increased 2.06-fold in 1982 compared to 1957 while the daily phytosterol intakes were both approximately 373 mg in 1957.

Table 7. Comparison of the intake ratios of phytosterol and fatty acids to cholesterol in 1957 and 1982.

| Ratio to cholesterol (g/g) | Composite diet | Ratio of 1982/1957 |
|---------------------------|----------------|-------------------|
|                           | 1957           | 1982              |                  |
| Fatty acid/Cholesterol    |                |                   |
| SFA/Cholesterol           | 35.5 ± 11.4    | 46.1 ± 3.7        | 1.30             |
| MUFA/Cholesterol          | 34.0 ± 10.1    | 51.9 ± 0.5        | 1.53             |
| PUFA/Cholesterol          | 42.7 ± 11.5    | 31.7 ± 0.6        | 0.74             |
| Phytosterol/Cholesterol   | 2.18 ± 0.62    | 1.00 ± 0.14       | 0.46             |

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and 1982. Considering that dietary phytosterol causes a decrease in serum cholesterol while cholesterol intake causes it to increase, we examined the dietary data and found that the transition from the 1957 to the 1982 diet is characterized by a decrease from 2.18 to 1.00 (g/g) in the daily phytosterol relative to cholesterol (Table 7). The ratio of phytosterol to cholesterol in 1982 was still greater than that for the diet of the general population of the United States (0.49) but lower than that for the vegetarians (3.26) (Table 5). The data appear to strongly indicate that the phytosterol/cholesterol ratio is a significant entity for distinguishing between diets of high and low risk for coronary artery disease. These results may suggest that the ratio of phytosterol/cholesterol is more significant in relation to the relative risk of coronary artery disease than the ratio of PUFA/cholesterol.

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