ORIGINAL CONTRIBUTION

Dietary Intake of Water-Soluble, Water-Insoluble and Total Fiber by General Japanese Populations at Middle Ages

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In order to assess current dietary intake of water-soluble, water-insoluble and total fiber, fiber contents were estimated from food items in 24-hour total duplicate samples, utilizing a recently published tables of dietary fiber in foods coupled with supplemental procedures for better coverage of food items. The food duplicates were collected from 370 middle-aged Japanese subjects in 18 study sites in 12 prefectures across Japan during a period from 1990 to 1993. The coverage by the original database was 86% on an average (by weight of crude fiber-containing foods), whereas the coverage was 99% when supplemental procedures were applied in addition. The average ingested amount was 3.2 g/day for water-soluble fiber and 18.3 g/day for total fiber. No sex- or age-dependent difference was observed. Thus, current dietary intake of fiber by middle-aged Japanese people appears to be marginally sufficient. The leading sources were vegetables both for soluble (1.4 g/day) and total fiber (6.2 g/day), followed by cereals (0.3 and 3.1 g/day, respectively), fruits (0.8 and 2.7 g/day) and then pulse (0.4 and 2.3 g/day). J Epidemiol, 1995; 197-204.

dietary fiber intake, Japanese diet, total fiber, water-insoluble fiber, water-soluble fiber

Dietary fiber is a group of complex natural food constituents, generally understood as plant materials that are resistant to digestion by human alimentary enzymes¹, although some of them are digestible and indeed contribute to human energy requirements². Increasing attention has recently been focused on dietary fiber intake, because fiber in the diet appears to have multiple beneficial potentials, e.g., reduced absorption of toxic heavy metals such as cadmium³, and possible contribution to the prevention of colo-rectal cancer⁴-⁸ as well as ischemic heart diseases⁹, in addition to well-known laxative effects¹⁰.

It has been made clear that the health-related effects of dietary fiber differ depending on physico-chemical properties such as water solubility¹¹. Water-soluble fiber may play a major role in hypoglycemic¹²-¹³ and hypolipidemic effects¹⁴,¹⁵ whereas water-insoluble fiber may contribute to laxation by increasing stool bulk¹⁰,¹². Some types of fiber may exhibit both effects together¹⁶. Thus, dietary fiber intake should be evaluated not only as whole fibrous materials but separately for soluble and insoluble fiber.

Recently, a data-base was published in Japan for estimation of fiber contents in over 200 food items¹⁷, which also allows independent quantification of soluble and insoluble fiber in most of the food items. The present study was initiated to estimate intakes of total dietary fiber, water-soluble and -insoluble fiber among adult general Japanese population. Efforts were made to establish a method for estimation of dietary fiber intakes from individual food items. For this purpose, supplemental procedures were introduced to cover the cases in which no data on soluble, insoluble and total fibers are available in the original fiber composition data-base¹⁷.

MATERIALS AND METHODS

Participants
The study was conducted in Japan in three winter seasons from 1990 to 1993. A total of 370 adult subjects (46 male farmers and 324 women, mostly house-wives of farmers) participated in the study. No random sampling...
strategy could be taken in recruiting the participants, but best efforts were made to collect them from various parts of the country, i.e., they lived in 18 study sites in 12 prefectures from the north-most Hokkaido Prefecture to the south-most Okinawa Prefecture in Japan as shown in Figure 1. Their ages distributed in a range of 30 to > 70 years, but mostly (i.e., by 67%) in 40-59 years.

**Collection of 24-hour total food duplicates, and calculation for energy and water-soluble/-insoluble fiber**

Collection of 24-hour food duplicates was conducted, following the procedures previously described. Each food item in the individual food duplicate was separated, and its weight was recorded. The code number of the food item was identified by a nutritionist in reference to the Standard Tables of Food Composition in Japan (STFCJ). Daily energy intake was estimated from the weight records utilizing the STFCJ data-base, and that of fiber with the Appendix on Dietary Fiber (FIBER). Food items calculated for dietary fibers were those in Groups 1 (cereals), 2 (potato and starch), 4 (confectionery), 6 (nuts and seeds), 7 (pulse), 12 (vegetables), 13 (fruits), 14 (fungi) and 15 (algae) after Resources Council. Soluble, insoluble and total fiber contents in foods tabulated in STFCJ were based on the method of Prosky and others and its modification with two exceptions for fungi and algae; a new method was used to avoid underestimation of chitin in fungi, and only total fiber contents were given for algae because separate determination of soluble and insoluble fiber was not possible.

The number of food items in the FIBER data-base (with 224 items) was less than 30% of the STFCJ data-base (with 776 items) (Table 1). Accordingly, the following supplemental procedures were taken for food items which were not available in the FIBER data-base, i.e.,

**A.** When the FIBER data-base was available only for uncooked food, the soluble and insoluble fiber contents in cooked food were estimated from the contents in the uncooked material, assuming that they were in proportion to crude fiber contents (given in the STFCJ data-base) for cooked and uncooked food; crude fiber is defined in the data-base as organic residues after step-wise treatment in 1.25% sulfuric acid and then in 1.25% sodium hydroxide. It was previously reported that cooking of vegetables under normal conditions will not induce marked changes in fiber composition. No data are available on other fiber-containing foods.

**B.** In case the FIBER data-base for the food in question was not available, the fiber composition was estimated from the value for other plants of the same biological family.

**C.** In case the food in question was known to be composed of several food items, fiber in the food was estimated by the summation of the components.

These supplemental procedures made it possible to calculate fiber contents in additional 227 food items (79, 58 and...
Table 1. Number of food items in the data-bases by food group.

| Food group | No. of items in existing data-bases | No. of items added by supplemental method | Total |
|------------|-----------------------------------|------------------------------------------|-------|
|            | STFCJ<sup>a</sup> | FIBER<sup>c</sup> | A<sup>d</sup> | B<sup>e</sup> | C<sup>e</sup> |       |
| 1. Cereals | 129 | 40 | 2 | 14 | 2 | 18 | 58 (45%) |
| 2. Potato & Starch | 24 | 9 | 4 | 4 | 0 | 8 | 17 (71%) |
| 4. Confectioneries | 97 | 0 | 0 | 0 | 85 | 85 | 85 (88%) |
| 6. Nuts & Seeds | 35 | 10 | 4 | 1 | 0 | 5 | 15 (43%) |
| 7. Pulse | 47 | 27 | 5 | 5 | 0 | 10 | 37 (79%) |
| 12. Vegetables | 255 | 87 | 42 | 21 | 0 | 63 | 150 (59%) |
| 13. Fruits | 110 | 26 | 3 | 10 | 0 | 13 | 39 (36%) |
| 14. Fungi | 31 | 13 | 6 | 5 | 0 | 11 | 24 (77%) |
| 15. Algae | 42 | 12 | 13 | 1 | 0 | 14 | 26 (62%) |
| Total | 776<sup>e</sup> | 24 | 79 | 58 | 90 | 227 | 451 (58%) |

<sup>a</sup>Grouping of food is after Resources Council<sup>22</sup>.
<sup>b</sup>Standard Tables of Food Composition in Japan<sup>22</sup>.
<sup>c</sup>Standard Tables of Food Composition in Japan, Appendix IV Fiber<sup>17</sup>.
<sup>d</sup>A, deduction from uncooked materials; B, estimation from a plant of the same biological family; C, estimation by summation of the components (for details, see Materials and methods).
<sup>e</sup>Five items in Group 8 (fish and shellfish) and 1 item in Group 9 (meat), i.e., canned fish meat cooked with tomato, are included.

90 items by Procedure A, B and C, respectively) so that 451 items in total were covered (Table 1).

Statistical analysis
A normal distribution was assumed for dietary fiber intake, as described in the results. Since standard deviations (SDs) were not always small enough as compared with means (Ms) (i.e., SD/M > 30%), medians were also calculated. There were, however, no material differences between Ms and medians, and thus the results were mostly presented in terms of M ± SD. Analysis of variance (ANOVA), multiple comparison test (Scheffe) and Student’s t-test (paired) were employed to examine statistical significance of the differences in means.

RESULTS

Estimation of fiber intake
As summarized in Table 2, the 370 study subjects consumed 2,416 g food/day on average with an energy intake of 1,908 kcal/day. Presence of crude fiber was identified by the STFCJ data-base in 1,143 g of foods or 47.3% of the

Table 2. Improved estimation of water-soluble and water-insoluble dietary fiber intake by supplemental procedures.

| Variable | Weight<sup>a</sup> (g/day) | (Percentage)<sup>b</sup> |
|----------|-----------------------------|--------------------------|
| Daily consumption of food | 2,416±597 |  | |
| Daily energy intake (kcal/day) | 1,908±448<sup>c</sup> |  | 
| Fiber-containing food<sup>d</sup> | 1,143±303 | (100%) |
| Without supplemental procedures | Amount of food | 984±271 | (86.2%) |
| | Amount of fiber | 13.5±5.3 |  |
| With supplemental procedures | Amount of food | 1,129±300 | (98.8%) |
| | Amount of fiber | 18.3±6.5<sup>**</sup> |  |

Calculation was made with 370 food duplicate samples. Asterisks indicate a significant (** for P < 0.01) increase in the amount as assayed by period t-test. For details of supplemental procedures, see Materials and methods.
<sup>a</sup>Sum of water-soluble and -insoluble fiber (M ± SD).
<sup>b</sup>Percentage over the amount of fiber-containing food.
<sup>c</sup>In kcal/day.
total food ingested. Calculation for dietary fiber with the FIBER data-base resulted in a dietary intake of 13.5 g total fiber/day in 984 g food, which accounted for 86% of the 1,143 g fiber-containing food. The mean coverage (in percentage) by study site ranged from 83 to 90%. On an individual basis, the coverage ranged from 47 to 100%.

The supplemental procedures significantly (P<0.01) increased the amount of food covered to 1,129 g/day, and the coverage was close to 100% with very small inter-study site variation. The minimum and the maximum coverage for individuals were 77 to 100%. The improvement was associated with a significant (P<0.01) increase in the estimate of daily intake of total dietary fiber to 18.3 g/day (Table 2).

The distribution of dietary intake of total fiber was almost symmetrical around the mean with a slight skewness towards higher values (Figure 2). The observation suggests that an assumption of normal distribution is applicable.

**Dietary fiber intake by sex and age group**

There was no material difference in dietary intakes of soluble, insoluble and total fiber between the two sexes (P>0.10). Thus, the study subjects (two sexes in combination) took 3.2±1.3 g soluble fiber and 13.4±12.8 g insoluble fiber/day as M±SD. When the subjects (men and women in combination) were classified by the decade of years of age, ANOVA followed by multiple comparison showed that the only significant (P<0.05) difference was in the intake of soluble fiber, in which the 40-49 year-old people took less fiber than the 60-69 year-old counterparts. There were no remarkable sex- and age-related difference, possibly because most of the study subjects were at 40 to 59 years of ages. Accordingly, the subjects of both sexes and different ages were combined for further analysis.

**Sources of dietary fiber by food groups**

In order to identify the major sources for soluble and insoluble fiber in Japanese food, fiber contents were classified by food groups as shown in Table 3. The combination of soluble and insoluble fiber in whole foods was 9% smaller than the total dietary fiber; this is because soluble and insoluble fibers were not calculated for seaweed-based foods. The leading fiber sources for the study population were vegetables accounting for about 34% of fiber from all foods, followed by cereals (17%), fruits (15%), pulse (13%), and algae (9%). It appeared likely that vegetables were not only the leading sources of both soluble and total fiber but the most contributing sources for soluble fiber, because the percentage of soluble fiber in the total was highest.

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**Table 3.** Food groups as sources of water-soluble, water-insoluble and total dietary fiber.

| Food group  | Water-soluble (g/day) | Water-insoluble (g/day) | Total (g/day) |
|-------------|-----------------------|-------------------------|--------------|
| 1. Cereals   | 0.3±0.4               | 2.7±1.0                 | 3.1±1.3      |
| 2. Potato & Starch | 0.1±0.2            | 0.9±0.9                 | 1.0±1.1      |
| 4. Confectioneries | 0.1±0.2            | 0.6±0.2                 | 0.7±1.3      |
| 6. Nuts & Seeds | 0.0                  | 0.2±0.5                 | 0.2±0.5      |
| 7. Pulse     | 0.4±0.4               | 1.9±2.0                 | 2.3±2.3      |
| 12. Vegetables | 1.4±0.8            | 4.8±2.2                 | 6.2±2.9      |
| 13. Fruits   | 0.3±0.8               | 1.9±1.9                 | 2.7±2.6      |
| 14. Fungi    | 0.0±0.1               | 0.4±0.7                 | 0.4±0.7      |
| 15. Algaec   | —                     | —                       | 1.7±2.3      |
| Sum         | 3.2±1.3 : 3.0         | 13.4±4.6 : 12.8         | 18.3±6.5 : 17.4 |

Values are ±SD: median.

*a*Grouping after Resources Council.

*b*Sum of water-soluble fiber and water-insoluble fiber.

*c*Fiber in algae cannot be separated for water-soluble and -insoluble fiber due to technical difficulties.
(23%) among the food groups (Table 3).

Prefectural and urban/rural difference in fiber intake

There were significant inter-prefectural difference in the intake of soluble (P<0.01 by ANOVA), insoluble (P<0.05) and total dietary fiber (P<0.01) (Table 4). Multiple comparison showed that urban residents in Tokyo and Kyoto each took significantly (P<0.01) less total fiber than farmers in Niigata, and that the farmers in Okinawa Islands took less soluble, insoluble and total fiber than the Niigata farmers (P<0.01 for each).

DISCUSSION

Dietary fiber intake by middle-aged Japanese people in different prefectures was calculated in the present study. It was found that people took 18.3 g fiber/day, of which soluble fiber accounted for about 17%. The intake of 18.3 g total fiber/day with an energy intake of 1,908 kcal/day or 9.6 g fiber/1,000 kcal energy/day marginally meets the recommended intake of 20 to 25 g fiber/day or 10 g fiber/1,000 kcal/day for adult Japanese28).

Reflecting increasing interests in the potential beneficial effects of dietary fibers, intake of dietary fiber by general populations has been estimated in 10 countries6-7,29-43) including Japan (where the present study was conducted) as listed in Table 5. The methods employed in estimating the amount of daily dietary fiber intake varies among the reports. Among the most common methods is the estimation based on national nutrition survey data combined with food composition tables38). For example, Niishimune et al. figured out a table of weighted mean total dietary fiber for 97 food groups44), and used the table to estimate the intakes of total dietary fiber from 1951-1990 National Nutrition Survey data40). Accuracy of the estimates naturally depends on the description of the national survey results and the coverage of the food composition data-base (even if it is correct). Diet recording and diet recall were also often employed, although diet recall may not be very quantitative in principle. It should also be taken into account that the fiber intake may vary depending on the age of the population45) and that secular changes in dietary fiber intake may exist46-47).

The overall inspection of the values so far reported (Table 5) suggests that the intakes were more or less similar around a value of 20 g/day in industrialized countries with one exceptional high value of 30 to 33 g/day in Swiss people39). Of particular interest is that the values for dietary fiber intake among Japanese populations are very close to each other regardless of variations in the methods used for estimation, i.e., 15 to 19 g/day29) or 18.8 g/day42) both by chemical analysis and 18.3 g/day in the present study. The estimate of 20.2 g/day based on 1979 National Nutrition Survey data30) appears to be somewhat higher than the values reported by other investigators29,40-41) but the difference may be smaller than it appears when the decreasing trends in fiber intake among Japanese population40,45) in this 10 year period is considered together. As the consumption of rice been decreasing47-48), the role of rice as a fiber source became less important, so that cereals (including rice) now takes only the 2nd position (Table 3). This may request more care of Japanese people to take sufficient dietary fiber from various sources other than rice.
Information is scarce on the intakes of soluble and insoluble fiber in various populations. In the only study available, Watanabe et al. estimated that Japanese people took 2.6 g soluble fiber, 12.2 g insoluble fiber and 16.0 g total fiber a day. These estimations are close but somewhat lower than the values obtained in the present study (Table 3). The major differences come from lower estimation of fiber intake from vegetables and fruits, the first and the third leading fiber sources (Table 3). In making estimation, Watanabe et al. also took advantages of the FIBER data-base, but in practice they summarized fiber contents into 44 representative food items. Underestimation in the study of Watanabe et al. as compared with the present study results would be due to the different practice in estimation, i.e., estimation in the food group basis in the study of Watanabe et al. and estimation on the basis of each and all food items in the present study.

In the present study, the proportion of soluble fiber was about 17%. In a Finnish study, the ratio was 22% in 39 men and 25% in 35 women in a Finnish study, and it was 16% in a study on Japanese population. In this connection, Ohnishi and Mori analyzed soluble and insoluble fiber in common vegetables available in Japan, and found that the fraction of soluble fiber among the total dietary fiber ranged from 19% in spinach to 27% in celery. Bearing in mind that vegetables as a whole are good sources of soluble fiber whereas most plant foods are rich in insoluble fiber, the proportion of 17% for soluble fiber in total dietary fiber in the present study appears to be reasonable. This observation facilitates the estimation of soluble fiber intake when only total fiber intake is known.

A program is currently in progress in this study group to establish a computerized system to estimate the amounts of soluble, insoluble and total dietary fibers in each food item when its code number and weight are available. The system will offer more convenient procedures to calculate fiber intake of individual persons.

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