Relationship of Food Intake and Dietary Patterns with Blood Pressure Levels Among Middle-Aged Japanese Men

Yutaka Takashima1, Yasuhiko Iwase2, Masao Yoshida1, Akatsuki Kokaze1, Yasushi Takagi3, Yoshitaka Tsubono4, Shoichiro Tsugane5, Tosei Takahashi2, Youji Iitoi2, Masayuki Akabane2, Shaw Watanabe2, and Takashi Akamatsu1

To investigate the relationship of food intake habits and dietary patterns to blood pressure, a cross-sectional study was conducted for 473 middle-aged Japanese males. After adjustment for age, residence, occupation, body mass index and alcohol consumption, mean systolic and diastolic blood pressure (SBP and DBP) were inversely associated with each intake frequency of dairy products, coffee, fruits, egg, beef, pork and chicken. The adjusted mean SBP and DBP of the individuals with 'all (=three)' of the following three dietary habits ; 'once and over / wk of dairy products', 'once and over / wk of fruits', and 'three times and over / wk of beef, pork or chicken', were 7.4mmHg and 6.9mmHg lower (p<0.001, for each) than those of 'zero or one' group. According to the analyses on 3-days weighed food records of 157 volunteers, the adjusted mean daily intake of total protein, animal protein and potassium were markedly higher in the 'two' or the 'three' group than in the 'zero or one' group (p<0.05, for each). These results suggest that habitual intake of dairy products, fruits, and meat or chicken may be associated with the reduction of blood pressure possibly through the intake of protein and potassium.

J Epidemiol, 1998 ; 8 : 106-115.

blood pressure, dietary pattern, food frequency questionnaire, weighed food record

Recent studies 1-10 have indicated the effects of dietary sodium, potassium, calcium, magnesium, fiber and protein on blood pressure. However, it is not necessarily feasible to incorporate these knowledge of individual nutrient in actual daily dietary life, since each food contains various kinds and amounts of nutrients beneficial or harmful to blood pressure in many cases. Therefore, as a practical approach for the prevention of hypertension, it is potentially important to recognize the effects of each food or dietary pattern on blood pressure properly. Although there have been many studies 12-14 assessing the significance of individual nutrient or food as a determinant of blood pressure, few studies 15-18 reported the combined effects of various foods on blood pressure. Appel LJ, et al.18 indicated from a clinical trial that a diet rich in fruits, vegetables, and low-fat dairy products and with reduced saturated and total fat could reduce blood pressure markedly under the condition that sodium intake and body weight were maintained at constant levels. This finding may suggest the combined effects of potassium, magnesium, calcium, fiber and possibly protein that occur together in food. Sufficient blood-pressure-lowering effects may be attained when the combination of the foods with nutritional composition exclusively beneficial to blood pressure are habitually taken, even if the blood-pressure-lowering effect of individual nutrient or food is not large. From these standpoints, in this study, which foods and dietary pattern closely relate to reduced blood pressure among middle-aged Japanese men, was explored referring also to nutrient intake data on the basis of a cross-sectional study.
METHODS

Subjects

As previously reported \(^{19,20}\), we obtained various personal data from a survey on dietary habits with health examinations that had been conducted during the period of February, 1989 through March, 1991 for 635 male residents aged 40 to 49, mostly randomly selected from five areas in Japan. The individual records of blood pressure and dietary habits represented by the intake frequency of each food among these data were the major materials of the present study. The five areas corresponded to the administrative districts of the five local public health centers (H.C.) ; Ninohe, H.C. of Iwate prefecture, Yokote, H.C. of Akita prefecture, Sakai, H.C. of Nagano prefecture, Katsushika-kita, H.C. of Tokyo prefecture and Ishikawa, H.C. of Okinawa prefecture. The number of participants in each of the five areas was as follows; Ninohe: 134, Yokote: 133, Sakai: 120, Katsushika-kita: 119, Ishikawa: 129. The number of initially randomly selected subjects was 170 in Ninohe, Yokote, Sakai and Ishikawa, and 200 in Katsushika-kita. Thus, the response rates in the survey varied from 59.5% to 78.8% among the five areas. Among a total of 635 participants, the individuals that met the following exclusion criteria were excluded from the analyses; individuals under treatment of hypertension, diabetes mellitus, cerebrovascular diseases, hepatobiliary diseases, peptic ulcer, cancer or any other chronic diseases; individuals whom a specific diet was administered; individuals who had abstained from alcohol drinking because of particular health problems; individuals whose records of height, weight, blood pressure or frequencies of food intake were incomplete. As a result, the remaining 473 subjects were subject to actual analyses. The occupation of these subjects was classified into the 11 categories according to the classification of the census in 1985 \(^{20}\).

Blood Pressure Assessment

In the health examinations, blood pressure was measured three times consecutively for each participant using the right arm by a digital recorder (Takeda Medical UA-850). Trained technicians, all of whom were instructed by one physician, carried out the measurements. All the measurements of blood pressure were conducted under sedate conditions. Systolic and diastolic blood pressure (SBP, DBP) from the third measurement were analyzed in the study under the assumption that the difference between the third and second measurement than the first and second measurements \(^{20}\). In the analysis on the relationship of blood pressure to the intake frequency of each food, in order to ensure the sufficient sample size of each frequency category, the above four categories were combined into the two or three categories. In addition, several dietary patterns were identified according to the intake frequency of each food. Thereafter, the associations of the dietary patterns to blood pressure were also analyzed. As for alcohol drinking, drinking frequency, the type of beverages regularly consumed and the number or amount of beverages consumed per occasion for each participant were ascertained by trained dietitians or public health nurses. Alcoholic beverages regularly consumed were classified into beer, sake, whiskey, shochu (including ‘awamori’), wine and brandy. From the investigation results of drinking habits and the established knowledge \(^{22,23}\) of ethyl-alcohol concentration in each beverage, total estimates of weekly alcohol consumption were calculated for each subject.

Furthermore, we conducted a survey on nutrient intake for a subgroup of the participants (207 volunteers) and their 183 spouses. The weighed food records over three consecutive weekdays were collected from them by a method used in the National Nutrition Survey \(^{20}\) with some modifications. In this survey, research dietitians instructed the subjects to record all foods and beverages prepared and consumed in a specially designed booklet. The participants were asked to provide detailed descriptions of each food, including the method of preparation and recipes whenever possible. A dietetic scale was provided for weighing food servings. For all foods eaten at home, the weights prepared and the proportions consumed by each man and the spouse were specified (e.g., 100g of rice was boiled and the man and the spouse consumed 50% and 30% of them, respectively). The dietitians checked the records at the participants’ home during the survey, and reviewed them in a standardized way after completion. As a result of this survey, a total of 154 food items were listed up, and referred to the Standard Tables of Food Composition in Japan \(^{24}\) with regard to the amount of nutrients per gram. Thereafter, for each participant, the levels of daily nutrient consumption were computed according to the following formula:

\[
\text{Intake level of nutrient } k = \sum_{i=1}^{154} Q_i D_{ik} \text{.}
\]

where \(Q = \) the grams of food consumed, \(D_k = \) amount of nutrient \(k\) per gram of food, \(i = \) identification number of food item. In this questionnaire survey, portion size information was not specified or asked for the food items other than rice, miso soup, Japanese tea and coffee, and thus semiquantitative estimates of nutrient intake were not obtained from the questionnaire. Intake frequency of each food was classified into the following four categories; ‘less than once a week’, ‘once or twice per week’, ‘three or four times per week’, and ‘almost everyday (which corresponds to five times and over per week)’. But in the analysis on the relationship of blood pressure to the intake frequency of each food, in order to ensure the sufficient sample size of each frequency category, the above four categories were combined into the two or three categories. In addition, several dietary patterns were identified according to the intake frequency of each food. Thereafter, the associations of the dietary patterns to blood pressure were also analyzed. As for alcohol drinking, drinking frequency, the type of beverages regularly consumed and the number or amount of beverages consumed per occasion for each participant were ascertained by trained dietitians or public health nurses. Alcoholic beverages regularly consumed were classified into beer, sake, whiskey, shochu (including ‘awamori’), wine and brandy. From the investigation results of drinking habits and the established knowledge \(^{22,23}\) of ethyl-alcohol concentration in each beverage, total estimates of weekly alcohol consumption were calculated for each subject.
Nutrients of which intake level was estimated according to this procedure, were as follows: total energy, protein, lipid, carbohydrate, calcium, phosphorus, iron, sodium, potassium, magnesium, and fiber. However, since the amount of magnesium and fiber per gram of food was listed only for a part of the foods in the Standard Tables of Food Composition in Japan, the intake levels of magnesium and fiber were estimated only from these foods with data of the amount of magnesium or fiber. Therefore, the individual intake levels of magnesium and fiber were possibly underestimated.

The aforementioned 473 subjects included 157 volunteers who had completed this nutrition survey.

**Statistical Analyses**

The SBP and DBP were compared between the two or three frequency categories of each food, and between the different categories of dietary pattern among the 473 subjects. In these comparisons, the SBP and DBP were adjusted for body mass index (BMI) which corresponds to weight (kg) divided by the square of height (m) and weekly alcohol consumption both known as important determinants of blood pressure. In addition, age, the five categories of residence and the 11 categories of occupation were also included as variables adjusted for. These adjusted means, which correspond to the least square means, were calculated by a multidimensional analysis of covariance using the LSMEANS option of the GLM procedure in the SAS statistical package. Similarly, the adjusted mean levels of daily nutrient intake were also compared between the categories of dietary pattern among the 157 subjects having the nutrition data. In this comparison, the mean levels of total energy intake were adjusted for age, occupation, residence, BMI, and weekly alcohol consumption. Other nutrients were further adjusted for total energy intake as a continuous variable. The adjustment for total energy intake was conducted by adding the total energy intake as a covariate in the multidimensional analysis of covariance using the GLM procedure, as shown in a previous study by Tsubono Y, et al.

**RESULTS**

The characteristics of 473 subjects are summarized in Table 1. The residences of the subjects were almost equally distributed into the five areas. Manual laborers (Craftsmen, production process workers and laborers) occupied about one-thirds of the subjects. As previously reported, there were some differences in blood pressure between the five areas. Moreover, the occupation was also associated with SBP and DBP. Among the 11 occupational categories, the mean SBP and DBP adjusted for age and residence were highest in ‘Workers in transport and communication’, whereas ‘Service workers’ showed the lowest adjusted mean values of SBP and DBP. The difference in adjusted mean values between the above two occupations were 12.9mmHg for the SBP (P=0.006) and 10.8mmHg for the DBP (P=0.001), respectively. Current smokers had 1.5mmHg (p=0.18) lower level of the mean DBP adjusted for age, residence, occupation, BMI and weekly alcohol consumption than non- or ex-smokers. In Table 2-(1),(2),(3) and (4), the adjusted mean SBP and DBP are compared between the categories of intake frequency in each food. The adjusted mean SBP and DBP were markedly lower in individuals with five times and over / wk than in those with less than once / wk in each intake of dairy products, coffee, egg and fruits. These differences in adjusted mean SBP and DBP were as follows: 5.8mmHg (p=0.003) and 5.0mmHg (p=0.001) for dairy products, 5.5mmHg (p=0.006) and 3.2mmHg (p=0.02) for coffee, 5.7mmHg (p=0.089) and 3.0mmHg (p=0.198) for egg, and 4.7mmHg (p=0.08) and 3.7mmHg (p=0.045) for fruits, respectively. Furthermore, there were inverse associations of the adjusted mean SBP or DBP with the intake frequency in each of beef, pork and chicken (p for trend=0.11 for SBP with beef, 0.066 for DBP with por and 0.159 for DBP with chicken, respectively), whereas fishes other than sardine, mackerel or Pacific saury was a positive correlate (p for trend=0.035 for SBP and 0.033 for DBP, respectively). As regards the intake of miso soup, the adjusted mean SBP and DBP were 2.4mmHg (p=0.251) and 2.0mmHg...
### Table 2-(1). Adjusted mean values † of systolic and diastolic blood pressure by the frequency of food intake

| Frequency of intake | Less than five times per week | Five times and over per week | p-value |
|---------------------|--------------------------------|-------------------------------|---------|
| Foods               | SBP (mmHg)                     | DBP (mmHg)                    |         |
| Japanese tea        | 121.8                          | 123.9                         | 0.229   |
|                     | 81.4                           | 82.8                          | 0.249   |
| (N=144)             | (N=329)                        |                               |         |
| Miso soup           | 125.2                          | 122.8                         | 0.251   |
|                     | 84.0                           | 82.0                          | 0.150   |
| (N=96)              | (N=377)                        |                               |         |
| Japanese Pickles    | 123.6                          | 123.0                         | 0.685   |
|                     | 82.6                           | 82.3                          | 0.784   |
| (N=213)             | (N=260)                        |                               |         |
| Snack and sweets    | 123.2                          | 123.9                         | 0.672   |
|                     | 82.7                           | 81.4                          | 0.270   |
| (N=349)             | (N=124)                        |                               |         |

†: adjusted for age, residence, occupation, body mass index and weekly alcohol consumption, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

### Table 2-(2). Adjusted mean values † of systolic and diastolic blood pressure by the frequency of food intake

| Frequency of intake | Low       | Medium    | High      | p-value | Low vs Medium | Medium vs High | Low vs High | for trend |
|---------------------|-----------|-----------|-----------|---------|---------------|----------------|-------------|----------|
| Foods               | SBP (mmHg)| DBP (mmHg)|           |         |               |                |             |          |
| Bread §             | 124.9     | 122.4     | 122.5     | 0.163   | 0.957         | 0.153          | 0.187       |
|                     | 83.9      | 81.6      | 81.7      | 0.065   | 0.945         | 0.116          | 0.081       |
| (N=199)             | (N=160)   | (N=114)   |           |         |               |                |             |          |
| Dairy Products ¶    | 127.4     | 121.8     | 121.6     | 0.005   | 0.917         | 0.003          | 0.005       |
|                     | 86.0      | 81.0      | 81.0      | <0.001  | 0.979         | <0.001         | <0.001      |
| (N=134)             | (N=164)   | (N=175)   |           |         |               |                |             |          |
| Coffee ¶            | 127.1     | 123.8     | 121.6     | 0.168   | 0.250         | 0.006          | 0.006       |
|                     | 84.6      | 82.8      | 81.4      | 0.270   | 0.307         | 0.021          | 0.020       |
| (N=104)             | (N=104)   | (N=265)   |           |         |               |                |             |          |
| Noodle ¶            | 123.4     | 122.3     | 125.1     | 0.665   | 0.098         | 0.563          | 0.230       |
|                     | 82.7      | 81.5      | 83.9      | 0.516   | 0.044         | 0.555          | 0.168       |
| (N=46)              | (N=254)   | (N=173)   |           |         |               |                |             |          |
| Potatoes §           | 122.4     | 123.3     | 124.0     | 0.718   | 0.693         | 0.532          | 0.526       |
|                     | 82.5      | 82.1      | 82.8      | 0.795   | 0.578         | 0.864          | 0.772       |
| (N=76)              | (N=239)   | (N=158)   |           |         |               |                |             |          |
| Soybean Products ¶   | 121.9     | 123.2     | 123.6     | 0.793   | 0.811         | 0.734          | 0.734       |
|                     | 80.9      | 82.0      | 83.0      | 0.750   | 0.376         | 0.532          | 0.328       |
| (N=34)              | (N=241)   | (N=198)   |           |         |               |                |             |          |

†: adjusted for age, residence, occupation, body mass index and weekly alcohol consumption, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, §: Low: less than once per week, Medium: once or twice per week, High: three times and over per week, ¶: Low: less than once per week, Medium: one to four times per week, High: five times and over per week
Table 2-(3). Adjusted mean values of systolic and diastolic blood pressure by the frequency of food intake

| Frequency of intake | Low   | Medium | High  | p-value     |
|---------------------|-------|--------|-------|-------------|
|                     | SBP(mmHg) | DBP(mmHg) | SBP(mmHg) | DBP(mmHg) | SBP(mmHg) | DBP(mmHg) | Low vs Medium | Medium vs High | Low vs High | for trend |
| Green or yellow     |       |        |       |             |
| Vegetables ‡        | 122.7 | 124.6  | 123.0 | 0.362       |
|                     | 81.5  | 84.2   | 82.0  | 0.068       |
|                     | (N=113)| (N=282)| (N=78) |             |
| White vegetables ‡  | 125.3 | 122.9  | 123.1 | 0.352       |
|                     | 81.8  | 82.4   | 82.6  | 0.730       |
|                     | (N=64)| (N=134)| (N=275) |             |
| Fruits ¶            | 128.5 | 121.8  | 123.8 | 0.007       |
|                     | 85.8  | 82.0   | 82.1  | 0.026       |
|                     | (N=63)| (N=231)| (N=179) |             |
| Seaweeds ‡          | 124.1 | 122.1  | 123.5 | 0.285       |
|                     | 82.6  | 81.9   | 82.8  | 0.556       |
|                     | (N=185)| (N=169)| (N=119) |             |
| Egg ¶               | 129.1 | 122.9  | 123.4 | 0.056       |
|                     | 85.5  | 82.2   | 82.5  | 0.141       |
|                     | (N=29)| (N=283)| (N=161) |             |

†: adjusted for age, residence, occupation, body mass index and weekly alcohol consumption, SBP: Systolic blood pressure, DBP: Diastolic blood pressure. ‡: Low: less than three times per week, Medium: three or four times per week, High: five times and over per week. ¶: Low: less than once per week, Medium: once to four times per week, High: five times and over per week

Table 2-(4). Adjusted mean values of systolic and diastolic blood pressure by the frequency of food intake

| Frequency of intake § | Low   | Medium | High  | p-value     |
|-----------------------|-------|--------|-------|-------------|
|                       | SBP(mmHg) | DBP(mmHg) | SBP(mmHg) | DBP(mmHg) | SBP(mmHg) | DBP(mmHg) | Low vs Medium | Medium vs High | Low vs High | for trend |
| Beef                  | 124.5 | 123.3  | 119.8 | 0.510       |
|                       | 82.0  | 83.6   | 79.3  | 0.183       |
|                       | (N=212)| (N=204)| (N=57) |             |
| Pork                  | 124.1 | 123.6  | 122.6 | 0.827       |
|                       | 84.2  | 82.7   | 81.2  | 0.311       |
|                       | (N=80)| (N=249)| (N=144) |             |
| Chicken               | 124.0 | 123.9  | 121.6 | 0.933       |
|                       | 83.0  | 83.5   | 80.1  | 0.645       |
|                       | (N=149)| (N=237)| (N=87) |             |
| Sardine, Mackerel or  | 122.3 | 123.8  | 123.2 | 0.556       |
| Pacific saury         | 81.1  | 83.1   | 82.2  | 0.249       |
|                       | (N=70)| (N=236)| (N=167) |             |
| Fishes other than the | 119.7 | 122.6  | 125.5 | 0.286       |
| Above three           | 80.2  | 81.8   | 84.0  | 0.383       |
|                       | (N=44)| (N=299)| (N=130) |             |

†: adjusted for age, residence, occupation, body mass index and weekly alcohol consumption, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, §: Low: less than once per week, Medium: once or twice per week, High: three times and over per week
(p=0.15) lower in ‘five times and over / wk’ group than in ‘less than five times / wk’ group, respectively. Next, we analyzed the relationships of the adjusted mean SBP and DBP to several dietary patterns. However, in this study, we present the results of a dietary pattern identified according to the intake frequency of dairy products, fruits, meat (beef and pork) and chicken which were found to be related to the SBP and DBP. In this analysis, regarding ‘once and over / wk of dairy products intake’, ‘once and over / wk of fruits intake’, and ‘three times and over / wk of intake of beef, pork or chicken’ as the three dietary habits beneficial to blood pressure, the subjects were classified into the following three groups ; ‘individuals who possess none or only one of the three habits’, ‘individuals who possess two of the three habits’, and ‘individuals who possess all (=three) of the three habits’. Table 3 shows the adjusted mean SBP and DBP by the three groups. In this table, the two results calculated according to the two linear models are shown. In model 1, the five items as shown in ‘methods’ (age, residence, occupation, BMI and weekly alcohol consumption) were included as the variables adjusted for. Model 2 was further adjusted for the three categories of coffee intake and intake of the fishes other than sardine, mackerel or Pacific saury, and the two categories of miso soup intake and smoking habit (current smoker, or non- or ex-smoker) which were also found to be more or less associated with SBP or DBP. The two results were quite similar. The number of the accompanying habits of the aforementioned three dietary habits was clearly inversely associated with the adjusted mean SBP and DBP (p for trend < 0.001 for SBP and DBP, in each of model 1 and model 2), and the differences in the adjusted mean values between the ‘zero or one’ group and the ‘three’ group in model 1 were 7.4mmHg for the SBP (p<0.001) and 6.9mmHg for the DBP (p<0.001), respectively. Additionally, the adjusted mean SBP and DBP were compared between the following three subgroups of the ‘two’ group ; (1) individuals whose intake habit of dairy products solely did not meet the above conditions (N=46), (2) individuals whose intake habit of meat or chicken solely did not meet the above conditions (N=179), (3) individuals whose intake habit of fruits solely did not meet the above conditions (N=15). In model 1, the adjusted mean SBP and DBP in these three subgroups were as follows; (1) : 124.7mmHg and 83.7mmHg, (2) : 122.3mmHg and 81.8mmHg, (3) : 130.6mmHg and 84.7mmHg, respectively. These adjusted mean SBP and DBP were all above the values in the ‘three’ group. In Table 4, the adjusted mean values of daily nutrient intake are shown by the number of the accompanying habits of the three dietary habits in the 157 volunteers with 3-days weighed food records. It was found that the adjusted mean values of total protein, animal protein, lipid, animal lipid, and potassium were all markedly higher in the ‘two’ or the ‘three’ group than in the ‘zero or one’ group (p<0.05, for each). In calcium, phosphorus, iron, magnesium and fiber also, the positive associations between adjusted mean values of daily intake and the number of the accompanying habits of the three dietary habits were noted, although the p-values for trend did not reach the 0.1 level for these five nutrients. Total energy,

**Table 3.** Adjusted mean (±SE) values of systolic and diastolic blood pressure according to the number of the accompanying habits of the three dietary habits † beneficial to blood pressure.

| Number of the beneficial habits | 'zero or one' (N=102) | 'two' (N=240) | 'three' (N=131) | 'zero or one' vs 'two' | 'zero or one' vs 'three' | 'two' vs 'three' | p-value for trend |
|--------------------------------|-----------------------|---------------|-----------------|----------------------|-----------------------|-----------------|-----------------|
| Adjusted mean (±SE) of SBP in model 1 ‡ (mmHg) | 127.9±2.5 | 123.3±2.2 | 120.5±2.3 | 0.023 | 0.124 | <0.001 | <0.001 |
| Adjusted mean (±SE) of SBP in model 2* (mmHg) | 128.8±2.6 | 123.9±2.3 | 120.8±2.4 | 0.014 | 0.093 | <0.001 | <0.001 |
| Adjusted mean (±SE) of DBP in model 1 ‡ (mmHg) | 86.7±1.7 | 82.4±1.5 | 79.8±1.5 | 0.002 | 0.041 | <0.001 | <0.001 |
| Adjusted mean (±SE) of DBP in model 2* (mmHg) | 87.4±1.8 | 82.9±1.6 | 79.9±1.7 | 0.001 | 0.017 | <0.001 | <0.001 |

SBP : Systolic blood pressure, DBP : Diastolic blood pressure, ‡ : ‘once and over per week of dairy products intake’, ‘once and over per week of fruits intake’, and ‘three times and over per week of intake of beef, pork or chicken’, * : model 1 was adjusted for age, residence, occupation, BMI and weekly alcohol consumption, † : model 2 was adjusted for age, residence, occupation, BMI, weekly alcohol consumption, the three categories of coffee intake and intake of the fishes other than sardine, mackerel or Pacific saury, and the two categories of miso soup intake and smoking habit.
Table 4. Adjusted mean (±SE) values ‡ of daily nutrient intake according to the number of the accompanying habits of the three dietary habits † beneficial to blood pressure in the 157 volunteers.

| Number of the beneficial habits | 'zero or one' (N=29) | 'two' (N=79) | 'three' (N=49) | 'zero or one' vs 'two' | 'two' vs 'three' | 'zero or one' vs 'three' | p-value | for trend |
|--------------------------------|---------------------|-------------|---------------|-----------------------|----------------|-----------------------|---------|---------|
| Total energy (Kcal)            | 2,441±87            | 2,441±59    | 2,370±73      | 0.034                 | 0.115          | 0.492                 | 0.746   |         |
| Carbohydrate (g)               | 297±7.9             | 290±5.3     | 297±6.6       | 0.385                 | 0.319          | 0.989                 | 0.883   |         |
| Protein (g)                    | 82±2.3              | 87±1.6      | 90±2.0        | 0.034                 | 0.228          | 0.005                 | 0.094   |         |
| Animal protein (g)             | 41±2.6              | 46±1.7      | 48±2.2        | 0.038                 | 0.527          | 0.018                 | 0.065   |         |
| Lipid (g)                      | 56±2.6              | 64±1.8      | 62±2.2        | 0.005                 | 0.525          | 0.041                 | 0.286   |         |
| Animal Lipid (g)               | 24±2.2              | 29±1.5      | 30±1.9        | 0.047                 | 0.665          | 0.033                 | 0.085   |         |
| Calcium (mg)                   | 495±37              | 553±25      | 551±31        | 0.148                 | 0.953          | 0.206                 | 0.409   |         |
| Phosphorus (mg)                | 1,233±33            | 1,301±22    | 1,343±27      | 0.054                 | 0.172          | 0.005                 | 0.145   |         |
| Iron (mg)                      | 11.8±0.4            | 12.3±0.3    | 12.6±0.4      | 0.288                 | 0.538          | 0.151                 | 0.359   |         |
| Sodium (mg)                    | 544±237             | 543±160     | 553±200       | 0.962                 | 0.716          | 0.745                 | 0.861   |         |
| Potassium (mg)                 | 264±109             | 295±273     | 2965±92       | 0.009                 | 0.901          | 0.014                 | 0.101   |         |
| Magnesium $                    | 256±88              | 262±5.9     | 268±7.4       | 0.518                 | 0.470          | 0.253                 | 0.490   |         |
| Fiber $                        | 120±7.2             | 128±10.4    | 13.2±0.6      | 0.272                 | 0.584          | 0.156                 | 0.237   |         |

†: 'once and over per week of dairy products intake', 'once and over per week of fruits intake', and 'three times and over per week of intake of beef, pork or chicken'. ‡: Total energy was adjusted for age, residence, occupation, body mass index and weekly alcohol consumption. Other nutrients were further adjusted for total energy intake as a continuous variable. $: Intake levels were estimated only from the foods of which amount of magnesium and/or fiber per gram are listed on the Standard Tables of Food Composition in Japan.

carbohydrate and sodium intake were not related to the number of these habits.

DISCUSSION

The present study suggested that in middle-aged Japanese men, habitual intake of dairy products, fruits, and meat or chicken may lower blood pressure. These results potentially reflect the beneficial influences of dietary protein, potassium, calcium and fiber which are considered to have favorable effects on blood pressure from the previous studies 2-10. This inference is supported by the results of nutrition intake data. The intake amount of protein, animal protein and potassium were substantially greater in the individuals who frequently consumed all of dairy products, fruits, and meat or chicken than in those who frequently consumed none or only one of these foods. Calcium was also positively associated with the number of the accompanying habits of the above three food intake habits, although the association seemed relatively weak. Since the nutrition survey was confined to 157 volunteers of 473 subjects, there may be a selection bias for this survey to some extent. However, the results of nutrition survey in Table 4 were considered to be well compatible with the group-specific nutrition intake status expected from the food frequency questionnaire for the entire subjects in Table 3. Sodium intake did not substantially differ between these three groups. It may imply that the observed relationship to blood pressure of this dietary pattern is unlikely to be explained by the sodium intake. However, we should be aware that the measurement error of sodium intake may not be small. Tsubono Y 31 indicated that the seasonings such as soysauce and salts were the major contributors of sodium consumption among Japanese by calculating the contribution rates of food items for the total population intake of nutrients in 180 Japanese men and their 155 spouses. Since the 3-days weighed food records may be inaccurate for the intake amount of seasonings, the validity of sodium intake level obtained from the records may be relatively low. In this sense, the relationship between the above dietary pattern and sodium intake should be further investigated by another research using sodium excretion level in 24-hours urine sample or a specifically designed semiquantitative food frequency questionnaire 31. The above dietary pattern was determined by the intake frequency of dairy products, fruits and meat or chicken, and not by egg intake. However, the observed inverse relationship of egg, one of the major sources of animal protein, to blood pressure might further ensure the beneficial effects of animal protein intake on blood pressure. Similarly, it may be interesting that miso soup intake was, though weakly, inversely associated with blood pressure. Miso soup is made from soybean which is rich in vegetable protein. Thus, this finding might also support the blood-pressure-lowering roles of protein. Historically, the increased protein intake had been thought to lead to a sustained increase in renal blood flow and glomerular filtration, and a chronic antirenal hyper-
tensive state 35,59. This concept had been linked to the assumption that protein intake has the adverse effects on blood pressure even among healthy individuals. However, recent results from several observational studies 5,10,34-37 strongly suggested the blood-pressure-lowering effects of protein intake or animal protein intake among general populations. Although Sacks FM, et al.10 demonstrated a lower blood pressure of vegetarians compared with omnivorous populations, the beneficial effects of dietary protein cannot be denied only from this finding. Also, it should be noted that the results among the people in Western countries cannot be simply applied to Japanese people. The overall intake amount of protein is undoubtedly quite different between Japanese and Western countries' people, and it is possible that the effects of dietary protein on blood pressure depend on the intake amount. However, we cannot see any intervention studies clarifying that the adequate intake of protein or animal protein actually lower blood pressure among human. It is because such intervention studies are still sparse, and the study designs among these few trials 38,39,40 are considered to be relatively inappropriate for verifying this subject. Further valid observational and experimental studies will be required to assess the significance of dietary protein or dietary amino acids as determinants of blood pressure.

On the other hand, potassium and calcium have been designated as the beneficial agents for blood pressure almost concordantly by previous observational or experimental studies 3-7. Therefore, there appears to be no problems in concluding that a reduced blood pressure among the individuals with all of the above three dietary habits may be in part due to the abundant intake of potassium and calcium. It was also found that the intake levels of magnesium and fiber were positively associated with the number of the accompanying habits of the aforementioned three dietary habits. As shown in the section of ‘Methods’, magnesium and fiber intake levels were likely to be underestimated, since these levels were computed only from the foods of which amount of magnesium or fiber per gram was documented in the Standard Tables of Food Composition in Japan. However, since the foods rich in magnesium or fiber were almost all selected as the foods with data of the amount of magnesium or fiber in the Tables, this observed positive relationship appears not to be a biased outcome. It may not be also ignorable that the adjusted mean intake of lipid and animal lipid were positively associated with the number of the accompanying habits of the three beneficial habits. It is uncertain whether dietary lipid or animal lipid can reduce blood pressure. Conversely, several studies 10,16,18,41 suggest that total fat or saturated fat is positively related to blood pressure, while the ratio of dietary polyunsaturated to saturated fatty acids is inversely associated with blood pressure. Since the noted positive relationship between lipid or animal lipid and the number of the beneficial habits was cleared off after further adjustment for total protein intake, the apparent relationship may be mostly derived from the confounding effects of the protein intake.

Whereas it is pointed out 33,40 that caffeine intake can raise blood pressure in the short term, the results from Multiple Risk Factor Intervention Trial (MRFIT) 38 and another study 10 showed the inverse relationship of usual caffeine intake to blood pressure levels. The results of Table 2-(2) in the present study may also reveal the blood-pressure-lowering effects of habitual caffeine intake by coffee.

It was interestingly found that there was a positive association between blood pressure and the intake frequency of fishes other than sardine, mackerel or Pacific saury. The reason for this finding was unclear. Since sodium intake was almost identical between the frequency categories of this food, sodium might not explain this association. A particular fatty acid or an amino acid specific in these fishes might contribute to raising blood pressure. But it is also possible that this association only reflect the confounding effects of other unknown factors.

The important finding of this study is that the reduction of blood pressure may be strengthened, especially when habitual intake of dairy products, fruits and meat or chicken occur together. Among the individuals with only ‘two’ of the three beneficial habits, the adjusted mean SBP and DBP were all above the values of the ‘all’ (=three) group in any of the three subgroups within the ‘two’ group. Accordingly, each of the three beneficial habits are likely to contribute to further decrease in blood pressure in addition to the effects of the other two habits among the ‘all’ group. As mentioned above, these results may show the combined effects of dietary protein (especially animal protein), calcium and potassium. However, we should be aware that each or the combination (data are not shown) of alternative foods rich in these nutrients, such as vegetables or fishes, was not associated with reduced blood pressure. Therefore, the clear relationship shown in Table 3 may be due not only to the mere combined effects of dietary protein, calcium and potassium but also to the favorable effects of other nutritional components in dairy products, fruits and meat or chicken. Or the absorption or the bioavailability of these beneficial nutrients might be enhanced especially through the intake of the above three foods.

In conclusion, this study attempted to illustrate some aspects of the overall effects of food intake and dietary patterns, and, as a result, may offer some clues in actual dietary life for preventing hypertension.

ACKNOWLEDGEMENTS

We are deeply indebted to Dr. Yoshimi Ichinowatari, M.D., Dr. Yoshiyuki Miyajima, M.D., Dr. Tenuo Ishibashi, M.D., Dr. Shosui Matsushima, M.D., Dr. Yoko Hirota, M.D., and Dr. Tsuneo Inami, M.D. for their full support in the present epidemiologic survey.
REFERENCES

1. Elliott P, Stamler J, Nichols R, et al. Intersalt revisited: further analyses of 24 hour sodium excretion and blood pressure within and across populations. BMJ, 1996 ; 312 : 1249-1253.

2. Dyer AR, Elliott P, Shipley M. Urinary electrolyte excretion in 24 hours and blood pressure in the INTERSALT study. II. Estimates of electrolyte-blood pressure associations corrected for regression dilution bias. Am J Epidemiol, 1994 ; 139 : 940-951.

3. Kesteloot H, Park BC, Brems-Heyns E, Claessens J, Joossens JV. A comparative study of blood pressure and sodium intake in Belgium and Korea. Eur J Cardiol, 1980 ; 11 : 169-182.

4. Ascherio A, Rimm EB, Giovannucci EL, et al. A prospective study of nutritional factors and hypertension among US men. Circulation, 1992 ; 86 : 1475-1484.

5. McCarron DA, Morris CD. Blood pressure response to oral calcium in persons with mild to moderate hypertension: A randomized, double-blind, placebo-controlled, crossover trial. Ann Intern Med, 1985 ; 103 : 825-831.

6. Grobbee DE, Hofman A. Effect of calcium supplementation on diastolic blood pressure in young people with mild hypertension. Lancet, 1986 ; 2 : 703-706.

7. Garcia-Palmieri, MR, Costas R, JR., Cruz-Vidal M, Sorlie PD, Tillotson J, Havlik RJ. Milk consumption, calcium intake, and decreased hypertension in Puerto Rico. Puerto Rico heart health program study. Hypertension, 1984 ; 6 : 322-328.

8. Obarzanek, E, Velletri PA, Cutler JA. Dietary protein and blood pressure. JAMA, 1996 ; 275 : 1598-1603.

9. Stamler J, Elliott P, Kesteloot H, et al. Inverse relation of dietary protein markers with blood pressure. Findings for 10020 men and women in the INTERSALT study. Circulation, 1996 ; 94 : 1629-1634.

10. Stamler J, Caggiula A, Grandits GA, Kjelsberg M, Cutler JA. Relationship to blood pressure of combinations of dietary macronutrients. Findings of the Multiple Risk Factor Intervention Trial (MRFIT). Circulation, 1996 ; 94 : 2417-2423.

11. Myers MG. Effects of caffeine on blood pressure. Arch Intern Med, 1988 ; 148 : 1189-1193.

12. Hata Y, Yamamoto M, Ohni M, Nakajima K, Nakamura Y, Takano T. A placebo-controlled study of the effect of sour milk on blood pressure in hypertensive subjects. Am J Clin Nutr, 1996 ; 64 : 767-771.

13. Green PJ, Suls J. The effects of caffeine on ambulatory blood pressure, heart rate, and mood in coffee drinkers. J Behav Med, 1996 ; 19 : 111-128.

14. Sung BH, Lovalo WR, Whitsett T, Wilson MF. Caffeine elevates blood pressure response to exercise in mild hypertensive men. Am J Hypertens, 1995 ; 8 : 1184-1188.

15. Sacks FM, Rosner B, Kass E. Blood pressure in vegetarians. Am J Epidemiol, 1974 ; 100 : 390-398.

16. Appel LJ, Moore TJ, Obarzanek E, et al. A clinical trial of the effects of dietary patterns on blood pressure. N Engl J Med, 1997 ; 336 : 1117-1124.

17. McCarron DA, Oparil S, Chait A, et al. Nutritional management of cardiovascular risk factors. A randomized clinical trial. Arch Intern Med, 1997 ; 157 : 169-177.

18. Beilin LJ, Burke V. Vegetarian diet components, protein and blood pressure: Which nutrients are important? Clin Exp Pharmacol Physiol, 1995 ; 22 : 195-198.

19. Tsugane S, Gey F, Ichinowatari Y, et al. Cross-sectional epidemiologic study for assessing cancer risks at the population level. 1. Study design and participation rate. J Epidemiol, 1992 ; 2 : 75-81.

20. Tsugane S, Gey F, Ichinowatari Y, et al. Cross-sectional epidemiologic study for assessing cancer risks at the population level. 2. Baseline data and correlation analysis. J Epidemiol, 1992 ; 2 : 83-89.

21. Statistics and Information department, Minister’s Secretariat, Ministry of Health and Welfare. Special report of vital statistics in 1990: Occupational and industrial aspects. Health and Welfare Statistics Association, Tokyo, 1990 : 249-251.

22. Kagawa A. Standard tables of food composition, 4th ed. Kagawa Nutrition University Press, Tokyo, 1995 : 286-289. (In Japanese)

23. Science and Technology Agency. Standard tables of food composition in Japan, 4th ed. Printing Bureau, Ministry of Finance, Tokyo, 1982. (In Japanese)

24. Ministry of Health and Welfare. Report of the national nutrition survey in 1992. Daichi-Shuppan, Tokyo, 1994. (In Japanese)

25. Takashima Y, Kokaze A, Iwase Y, et al. Drinking habit as a base for blood pressure elevation: Difference in epidemiological significance by beverage type. Appl Human Sci, 1997 ; 16 : 47-53.

26. Chiang BN, Perlman LV, Epstein FH. Overweight and hypertension: a review. Circulation, 1969 ; 39 : 403-421.

27. Searle SR, Speed FM, Milliken GA. Populations means in the linear model: An alternative to least square means. Am Statist, 1980 ; 34 : 216-221.
Y. Takashima, et al. 115

1997; 27: 310-315.
31. Tsubono Y, Takamori S, Kobayashi M, et al. A data-based approach for designing a semiquantitative food frequency questionnaire for a population-based prospective study in Japan. J Epid, 1996; 6: 45-53.
32. Meyer TW, Anderson S, Brenner BM. Dietary protein intake and the course of renal disease: the role of capillary hypertension and hyperfusion in the pathogenesis of progressive glomerular sclerosis. In: Horan MJ, Blaustein MP, Dunbar JB, Kachadorian W, Kaplan NM, Simopoulos AP, eds. NIH Workshop on Nutrition and Hypertension: Proceedings from a symposium. Biomedical Information Corp., New York, 1985.
33. Brenner BM, Meyer TW, Hostetter TH. Dietary protein intake and the progressive nature of kidney disease: the role of hemodynamically mediated glomerular injury in the pathogenesis of progressive glomerular sclerosis in aging, renal ablation, and intrinsic renal disease. N Engl J Med, 1982; 307: 652-659.
34. Yamori Y, Kihara M, Nara Y, et al. Hypertension and diet: multiple regression analysis in a Japanese farming community. Lancet, 1981; 1: 1204-1205.
35. Kihara M, Fujikawa J, Ohtaka M, et al. Interrelationships between blood pressure, sodium, potassium, serum cholesterol, and protein intake in Japanese. Hypertension, 1984; 6: 736-742.
36. Reed D, McGee D, Yano K, Hankin J. Diet, blood pressure, and multicollinearity. Hypertension, 1985; 7: 405-410.
37. Zhou B, Zhang X, Zhu A, et al. The relationship of dietary animal protein and electrolytes to blood pressure: a study on three Chinese populations. Int J Epidemiol, 1994; 23: 716-722.
38. Prescott SL, Jenner DA, Beilin LJ, Margetts BM, Vandongen R. Controlled study of the effects of dietary protein on blood pressure in normotensive humans. Clin Exp Pharmacol Physiol, 1987; 14: 159-162.
39. Sacks FM, Kass EH. Low blood pressure in vegetarians: effects of specific foods and nutrients. Am J Clin Nutr, 1988; 48: 795-800.
40. Kestin M, Rouse IL, Correll RA, Nestel PJ. Cardiovascular disease risk factors in free-living men: comparison of two prudent diets, one based on lacto-ovo-vegetarianism and the other allowing lean meat. Am J Clin Nutr, 1989; 50: 280-287.
41. Sacks FM. Dietary fats and blood pressure: a critical review of the evidence. Nutr Rev, 1989; 47: 291-300.