OBJECTIVE — Dietary patterns in Western populations have been linked to type 2 diabetes, but the role of diet in Japanese remains unclear. We investigated the association between major dietary patterns and glucose tolerance status as measured by A1C in Japanese adults.

RESEARCH DESIGN AND METHODS — The groups of subjects were comprised of 3,243 men and 4,667 women who participated in the baseline survey of an ongoing cohort study on lifestyle-related diseases in Fukuoka, Japan. Dietary patterns were derived by using principal-component analysis of the consumption of 49 food items, ascertained by a food-frequency questionnaire. Logistic regression analysis was used to estimate sex-specific odds ratios (ORs) of elevated A1C (≥5.5%), with adjustment for potential confounding variables.

RESULTS — The Westernized breakfast pattern characterized by frequent intake of bread but infrequent intake of rice was inversely related to A1C concentrations (Ptrend = 0.02 in both men and women); the multivariate-adjusted ORs for the highest versus lowest quintiles were 0.60 (95% CI 0.43–0.84) and 0.64 (0.46–0.90) for men and women, respectively. The seafood dietary pattern was positively associated with A1C concentrations in men only (Ptrend = 0.01). Neither the healthy nor high-fat dietary pattern was related to A1C.

CONCLUSIONS — A dietary pattern featuring frequent intake of white rice may deteriorate glucose metabolism in Japanese men and women, and the salty seafood dietary pattern may have a similar effect in men.

The prevalence of type 2 diabetes is increasing worldwide (1). Likewise, the Japanese, who have experienced rapid economic growth during the past several decades, now have a high prevalence of type 2 diabetes (2). However, this situation seems peculiar given that obesity, a strong determinant of the disease (3), is much less common among Japanese than among Western populations (4,5). It has been postulated that the Japanese are predisposed to type 2 diabetes because of their low levels of insulin secretion and sensitivity, which may be determined by both genetic and environmental factors (4,5). The investigation of a Japanese diet in relation to type 2 diabetes may provide a clue to the issue.

The relation of specific foods and nutrients such as vegetables (6), dietary fiber (7), and glycemic load (8) to risk of type 2 diabetes has been examined in many studies, but few have addressed the association with dietary patterns. Although the effect of a single nutrient, food, or food group on disease risk and morbidity conditions has often been investigated, such an effect is difficult to assess in observational studies because foods and nutrients are consumed in combination, and their complex effects are likely to be interactive or synergistic (9). To overcome problems relating to the close intercorrelation among foods or nutrients, analysis of dietary patterns has gained much interest. A dietary pattern is a comprehensive variable that integrates consumption of several foods or food groups and is expected to have a greater impact on disease risk than any single nutrient (9). Studies in Western populations have suggested that risk of type 2 diabetes is associated inversely with prudent or healthy dietary patterns (10–12) and positively with a Western dietary pattern (11–14). To the best of our knowledge, however, only one study reported an association between a Japanese dietary pattern and type 2 diabetes (13). The aim of the present study was, therefore, to investigate dietary patterns in relation to glucose tolerance status as measured by A1C concentrations in Japanese adults.
Dietary assessment
The food-frequency questionnaire method was used to assess intakes of 60 food and beverage items on average over the past year. Dietary questions were derived primarily from the 47-item food-frequency questionnaire (17), which was validated with 3-day weighted diet records; most of the nutrients showed correlation coefficients of 0.4–0.6 (18). Frequency of consumption of staple foods (rice, bread, and noodles) was measured on a scale of six categories ranging from almost null to daily for each breakfast, lunch, and supper. Regarding food items other than the staple foods, participants answered consumption frequency by choosing one of eight options ranging from almost null to three or more times/day. The reported frequency of consuming each food was converted to a frequency of consumption per week, with somewhat conservative values assigned to greater frequency categories: 0.5 to 1 time/day, 1.0 to 2 times/day, and 1.5 to 3 times/day. Regarding each of the staple foods, values of weekly frequency (0–6.5) were summed over the three meals. The amount consumed per occasion was asked for the staple foods, but this information was not used.

Statistical analysis
We performed principal component analysis based on 49 food items to derive dietary patterns; questions of beverages (six items) and dishes (five items) were not considered. Principal component analysis is a technique to reduce a number of variables into fewer independent factors. The factors were rotated by orthogonal transformation (varimax rotation) to maintain uncorrelated factors and greater interpretability. We considered eigenvalues, the scree test, and the interpretability of the factors to determine the number of factors to retain. The factors satisfied the criteria for eigenvalues > 1, and the scree plots dropped substantially after the third factor (from 2.37 to 1.68) and remained similar after the fourth factor (1.47 for the fifth and 1.40 for the sixth factor); thus, we decided to retain four factors. We confirmed that when the analysis was done separately for men and women, similar dietary patterns were extracted for each sex. Dietary patterns were named according to the food items showing high loading (absolute value) on each of four factors. The factor scores for each dietary pattern and for each individual were calculated by summing intakes of food items weighted by their factor loadings. Factor scores were categorized into quintiles based on the distribution for men and women separately.

The confounding variables considered were age (years), BMI (< 22.5, 22.5–24.9, 25.0–27.4, and ≥ 27.5 kg/m2), smoking (lifetime nonsmoker, former smoker, and current smoker with a consumption of < 20 or ≥ 20 cigarettes/day), alcohol consumption (nondrinker, former drinker, and current drinker with a consumption of < 30, 30–59, or ≥ 60 g ethanol/day), physical activity (quartile of MET hours per week), and parental history of diabetes (absent or present). The trend was assessed by using the Mantel-Haenszel $\chi^2$ test for categorical variables and linear regression analysis for continuous variables, assigning ordinal numbers 0–4 to quintile categories of each dietary pattern.

We defined high levels of A1C concentration according to the definition used in the National Health and Nutrition Survey in Japan, in which those with A1C concentrations of 5.5–6.0 and ≥ 6.1% were regarded as having “possible” and “probable” diabetes, respectively. The cutoff of 5.5% for A1C gave a sensitivity of 80.1% and a specificity of 78.5%, and A1C of 6.1% corresponded with a 2-h plasma glucose level of 200 mg/dl in an oral glucose tolerance test (19). Multiple logistic regression was performed to estimate the odds ratio (OR) and 95% CI of elevated A1C (≥ 5.5%) according to quintiles of scores for each dietary pattern, taking the lowest quintile group as the reference. The first model was adjusted for age only, and the second model was further adjusted for BMI, smoking, alcohol consumption, physical activity, and parental history of diabetes. Because the results were similar in these models, we present the fully adjusted results only. Trend association was assessed by assigning ordinal numbers 0–4 to quintile categories of each dietary pattern. We repeated the analysis by using a more specific outcome criterion (A1C concentrations of ≥ 6.1%) while excluding subjects who had A1C concentrations of 5.5–6.0%. Two-sided P values < 0.05 were regarded as statistically significant. All analyses were performed using SAS (version 8.2; SAS Institute, Cary, NC).

RESULTS — We identified four dietary patterns by principal component analysis (Table 1). The first factor was named a healthy dietary pattern because it represented frequent consumption of vegetables, fruit, soy products, fish, and yogurt. The second factor was characterized by frequent consumption of fried food, meat, processed meat, mayonnaise, and egg, and thus it was named a high-fat dietary pattern. The third factor represented frequent consumption of a variety of seafoods including shellfish, salted fish guts, fish roe, and fish paste products, and the pattern was named a seafood dietary pattern. The fourth factor was a Westernized breakfast pattern characterized by frequent consumption of bread, margarine, and coffee and infrequent consumption of rice and miso soup. The first to fourth dietary patterns accounted for 16.8, 5.5, 4.8, and 3.4%, respectively, of the variance in food intakes and totally explained 30.5% of the variability.

The characteristics according to quintile categories of dietary pattern scores are shown in Table 2. In both men and women, participants with a higher score of the healthy dietary pattern were more likely to be older and physically active in leisure time and were less likely to be a smoker and alcohol drinker. Participants with a higher score of the high-fat dietary pattern were on average younger and more likely to be a smoker. The high-fat dietary pattern was also associated positively with BMI and inversely with physical activity in leisure time in women. Both men and women with a higher score of the seafood dietary pattern tended to drink alcohol more frequently and have higher BMI. Women, but not men, with a higher score of the Westernized breakfast pattern were more likely to be older, and physically active in leisure time, and were less likely to be a smoker and alcohol drinker. Participants with a higher score of the seafood dietary pattern were more likely to be a smoker and alcohol drinker. Participants with a higher score of the high-fat dietary pattern were on average younger and more likely to be a smoker.
Table 1—Factor-loading matrix for major dietary patterns identified by principal component analysis

| Item                                | Healthy pattern | High-fat pattern | Seafood pattern | Westernized breakfast pattern |
|-------------------------------------|-----------------|------------------|-----------------|-------------------------------|
| Green-leaf vegetables               | 0.67            | 0.16             | —               | —                             |
| Carrots                             | 0.66            | 0.28             | —               | —                             |
| Mushrooms                           | 0.66            | 0.19             | —               | —                             |
| Other green-yellow vegetables       | 0.65            | 0.22             | —               | —                             |
| Other vegetables                    | 0.65            | 0.35             | —               | —                             |
| Seaweeds                            | 0.63            | —                | —               | —16                           |
| Daikon (Japanese radish)            | 0.61            | 0.17             | —               | —15                           |
| Potatoes                            | 0.61            | 0.25             | —               | —                             |
| Other fruits                        | 0.60            | —                | —               | 0.23                          |
| Pumpkin                             | 0.57            | —                | —               | —                             |
| Cabbage                             | 0.55            | 0.35             | —               | —                             |
| Citrus fruits                       | 0.54            | —                | —               | —                             |
| Broccoli                            | 0.49            | —                | —               | —                             |
| Burdock/bamboo shoots               | 0.46            | 0.15             | 0.19            | —                             |
| Bone-edible small fish              | 0.46            | —                | 0.34            | −0.15                         |
| Natto and soybean                   | 0.46            | —                | —               | —                             |
| Tofu products                       | 0.44            | 0.20             | 0.21            | —                             |
| Yogurt                              | 0.42            | −0.19            | —               | 0.25                          |
| Fish                                | 0.37            | —                | 0.31            | —                             |
| Kiriboshi-daikon*                   | 0.35            | —                | 0.26            | —                             |
| Tofu (soybean curd)                 | 0.35            | —                | 0.22            | —                             |
| Japanese confectioneries            | 0.32            | —                | —               | 0.16                          |
| Deep-fried foods                    | —               | 0.59             | 0.25            | —                             |
| Beef/pork                           | —               | 0.58             | —               | —                             |
| Stirred foods                       | 0.29            | 0.57             | —               | —                             |
| Mayonnaise                          | —               | 0.54             | 0.16            | —                             |
| Chicken                             | —               | 0.49             | —               | —                             |
| Ham, sausage, and bacon             | —               | 0.43             | 0.16            | 0.25                          |
| Egg                                 | —               | 0.35             | 0.22            | —                             |
| Squid/octopus and shrimp/crab       | —               | —                | 0.61            | —                             |
| Shellfish                           | 0.20            | —                | 0.60            | —                             |
| Fish roe                            | —               | —                | 0.52            | —                             |
| Salted fish guts                    | —               | —                | 0.43            | —                             |
| Fish paste products                 | —               | 0.31             | 0.39            | —                             |
| Tsukudani†                          | —               | —                | 0.37            | —                             |
| Bread                               | —               | —                | —               | 0.79                          |
| Margarine                           | —               | —                | —               | 0.56                          |
| Coffee                              | —               | 0.21             | —               | 0.31                          |
| Miso soup                           | 0.30            | —                | —               | −0.47                         |
| Rice                                | —               | —                | —               | −0.74                         |

Factor loadings less than ±0.15 are represented by a dash for simplicity. Omitted in the table are food items with factor loadings less than ±0.30 for all dietary patterns (green tea, peanut/almond, garlic, canned tuna, milk, liver, Western-style confections, butter, and noodles). *Dried strips of daikon (Japanese radish); †Seasoods simmered in soy and sugar.

pattern were younger and had lower BMI, and they were more likely to be a smoker and physically active. The Westernized breakfast pattern was positively associated with the frequency of alcohol drinking in women, whereas the opposite was observed in men.

The ORs of elevated A1C (≥5.5%) according to quintile categories of each dietary pattern score are shown in Table 3. Of the subjects, 442 men (13.6%) and 514 women (11.0%) were identified as having elevated A1C concentrations. The Westernized breakfast pattern was significantly and inversely related to the prevalence of elevated A1C in both men and women. Multivariate-adjusted ORs (95% CI) of elevated A1C for the highest versus lowest quintile of the Westernized breakfast pattern score were 0.60 (0.43–0.84) and 0.64 (0.46–0.90) for men and women, respectively. The seafood dietary pattern was positively related to the prevalence of elevated A1C in men. The odds of having elevated A1C for the fourth quintile of the seafood dietary pattern score was increased by >70% compared with that for the lowest quintile. Such an association was not observed in women. The healthy and high-fat dietary patterns were not statistically significantly related to the prevalence of elevated A1C.

In an additional analysis using a stricter definition of outcome (A1C ≥6.1%), the associations with the seafood and Westernized breakfast patterns were strengthened in men. Multivariate-adjusted ORs (95% CI) for elevated A1C for the second, third, fourth, and fifth quintiles versus the lowest quintile of the seafood dietary pattern were 1.22 (0.62–2.40), 1.92 (1.03–3.59), 2.08 (1.10–3.93), and 2.25 (1.20–4.19), respectively (\( P_{\text{trend}} = 0.003 \)). The corresponding values for the Westernized breakfast pattern were 0.60 (0.35–1.05), 0.77 (0.45–1.31), 0.49 (0.27–0.88), and 0.51 (0.29–0.90), respectively (\( P_{\text{trend}} = 0.02 \)). The associations with other dietary patterns in men and those with any pattern in women were not statistically significant.

**Conclusions**— We investigated the relationship between major dietary patterns and glucose tolerance status as measured by A1C concentrations in Japanese adults. Of the four dietary patterns we identified, the Westernized breakfast pattern was inversely related to A1C concentrations in both men and women, and the seafood dietary pattern was positively related to A1C concentrations in men but not in women.

Major strengths of the present study include large sample size, adjustment of known and suspected risk factors of type 2 diabetes, and the use of measured A1C concentrations as the outcome. Our study also had some limitations. First, an association derived from a cross-sectional study does not necessarily indicate causality. However, we excluded participants with health conditions that might affect dietary habit or A1C concentrations to minimize the possibility of reverse causality. Second, the present study was based on data from the baseline survey of a cohort study, in which one-fourth of the eligible individuals participated. We had no information about lifestyle characteristics of nonparticipants, but compared with that in the National Health and Nutrition
Table 2—Characteristics according to quintile categories of dietary pattern scores

|                          | Age (years) | BMI (kg/m²) | Smoking (current) | Alcohol use (current) | Physical activity* | Parental history of diabetes |
|--------------------------|-------------|-------------|-------------------|-----------------------|--------------------|-----------------------------|
| **Men**                  |             |             |                   |                       |                    |                             |
| Healthy dietary pattern  |             |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 58.6 ± 6.1  | 23.6 ± 2.9  | 51.1              | 77.8                  | 8.6                | 10.2                        |
| Quintile 5 (high)        | 65.2 ± 6.4  | 23.4 ± 2.5  | 21.0              | 69.1                  | 22.4               | 11.0                        |
| \( P_{\text{trend}} \) | <0.01       | 0.60        | <0.01             | <0.01                 | <0.01              | <0.01                       |
| High-fat dietary pattern |             |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 63.3 ± 6.5  | 23.5 ± 2.8  | 28.9              | 72.8                  | 15.7               | 9.3                         |
| Quintile 5 (high)        | 60.3 ± 7.0  | 23.6 ± 2.9  | 35.6              | 74.7                  | 14.4               | 12.2                        |
| \( P_{\text{trend}} \) | <0.01       | 0.30        | <0.01             | 0.11                  | 0.55               | 0.17                        |
| Seafood dietary pattern  |             |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 61.7 ± 6.8  | 23.3 ± 2.7  | 32.6              | 64.8                  | 15.0               | 11.4                        |
| Quintile 5 (high)        | 62.4 ± 6.9  | 23.8 ± 3.0  | 34.3              | 80.1                  | 15.6               | 12.3                        |
| \( P_{\text{trend}} \) | 0.14        | <0.01       | 0.62              | <0.01                 | 0.78               | 0.53                        |
| Westernized breakfast pattern |       |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 62.5 ± 6.4  | 23.7 ± 2.8  | 29.8              | 79.2                  | 15.6               | 11.4                        |
| Quintile 5 (high)        | 62.2 ± 7.0  | 23.6 ± 2.7  | 33.5              | 70.4                  | 15.9               | 11.1                        |
| \( P_{\text{trend}} \) | 0.36        | 0.09        | 0.11              | <0.01                 | 0.63               | 0.76                        |
| **Women**                |             |             |                   |                       |                    |                             |
| Healthy dietary pattern  |             |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 58.7 ± 6.3  | 22.6 ± 3.3  | 14.5              | 33.9                  | 7.3                | 15.2                        |
| Quintile 5 (high)        | 64.3 ± 6.6  | 22.6 ± 3.0  | 2.0               | 23.0                  | 20.5               | 12.4                        |
| \( P_{\text{trend}} \) | <0.01       | 0.85        | <0.01             | <0.01                 | <0.01              | <0.01                       |
| High-fat dietary pattern |             |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 63.4 ± 6.4  | 22.4 ± 2.9  | 5.0               | 25.2                  | 16.4               | 14.0                        |
| Quintile 5 (high)        | 60.0 ± 6.9  | 22.7 ± 3.0  | 8.5               | 27.8                  | 11.1               | 15.5                        |
| \( P_{\text{trend}} \) | <0.01       | 0.03        | <0.01             | 0.06                  | <0.01              | 0.14                        |
| Seafood dietary pattern  |             |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 60.6 ± 6.5  | 22.3 ± 3.0  | 5.6               | 23.2                  | 13.3               | 14.9                        |
| Quintile 5 (high)        | 63.3 ± 7.1  | 22.9 ± 3.1  | 6.1               | 29.3                  | 16.3               | 11.7                        |
| \( P_{\text{trend}} \) | <0.01       | <0.01       | 0.31              | <0.01                 | 0.04               | 0.02                        |
| Westernized breakfast pattern |       |             |                   |                       |                    |                             |
| Quintile 1 (low)         | 62.8 ± 6.6  | 22.8 ± 3.3  | 5.7               | 25.3                  | 10.9               | 12.4                        |
| Quintile 5 (high)        | 60.8 ± 6.9  | 22.1 ± 2.8  | 7.5               | 31.0                  | 16.4               | 13.6                        |
| \( P_{\text{trend}} \) | <0.01       | <0.01       | 0.04              | 0.02                  | <0.01              | 0.38                        |

Data are means ± SD or %. *High recreational physical activity of ≥21 MET h/week. †Based on the Mantel-Haenszel \( \chi^2 \) test for categorical variables and linear regression analysis for continuous variables, assigning ordinal numbers 0–4 to quintile categories of each dietary pattern.

Survey (20), the study participants had lower smoking prevalence (<5%) and lower mean A1C levels (0.2–0.3%) in both sexes and virtually all age-groups. This fact may suggest that participants had, on average, healthier lifestyles and better physical condition than nonparticipants. However, the differences appear to be moderate and thus unlikely to account for the present association. Nevertheless, the low participation rate may have somewhat distorted the diet-A1C associations. We infer that, in the case of a high participation rate, more pronounced associations would have been observed because of a presumably greater variation in both the exposure and the outcome among the study population. Third, estimation of total energy and nutrient intakes from the present questionnaire has not yet been completed. Because a higher score on a dietary pattern is probably related to greater energy intake and thus may confer type 2 diabetes risk, the lack of adjustment for energy intake might be an explanation for the positive association between the Westernized breakfast pattern or for the seafood dietary pattern. However, energy adjustment should strengthen, rather than diminish, the inverse association between the Westernized breakfast pattern and A1C, which constitutes the major finding of the present study. Finally, there are limitations inherent to principal component analysis owing to arbitrary decisions in determining the number of factors to retain, in choosing the method of rotation of the initial factors, and in labeling the dietary patterns (9,21). In this regard, it is notable that dietary patterns extracted in the present study have also been identified elsewhere in Japan (15).

The Westernized breakfast pattern, characterized by frequent intake of bread, margarine, and coffee and infrequent intake of rice and miso soup, was inversely related to the prevalence of elevated A1C. This finding is in line with our previous observation in male self-defense officials (15). The quantity and quality of carbohydrate affect glucose and insulin responses (22). The glycemic indexes of bread and rice are comparable (23), and thus simple replacement of rice by bread does not affect the index. However, bread is usually consumed with other Western
Dietary patterns and A1C

Table 3—Multivariate-adjusted ORs (95% CI) of elevated A1C (≥5.5%) according to quintile categories of dietary pattern scores

| Dietary Pattern                  | Quintile 1 (low) | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 (high) | P trend* |
|---------------------------------|------------------|------------|------------|------------|-------------------|---------|
| Healthy dietary pattern         | 1.00             | 0.86 (0.62–1.21) | 0.75 (0.53–1.06) | 1.11 (0.80–1.54) | 0.84 (0.59–1.20) | 0.89    |
| High-fat dietary pattern        | 1.00             | 0.86 (0.62–1.18) | 0.80 (0.58–1.18) | 0.76 (0.55–1.06) | 0.74 (0.53–1.04) | 0.07    |
| Seafood dietary pattern         | 1.00             | 1.13 (0.80–1.61) | 1.31 (0.92–1.84) | 1.77 (1.26–2.47) | 1.34 (0.95–1.89) | 0.01    |
| Westernized breakfast pattern   | 1.00             | 0.70 (0.51–0.97) | 0.80 (0.58–1.09) | 0.80 (0.59–1.10) | 0.60 (0.43–0.84) | 0.02    |

Women

| Dietary Pattern                  | Quintile 1 (low) | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 (high) | P trend* |
|---------------------------------|------------------|------------|------------|------------|-------------------|---------|
| Healthy dietary pattern         | 1.00             | 1.37 (1.00–1.89) | 1.10 (0.80–1.53) | 1.21 (0.87–1.67) | 1.38 (1.00–1.91) | 0.18    |
| High-fat dietary pattern        | 1.00             | 0.96 (0.71–1.30) | 1.18 (0.88–1.58) | 1.02 (0.75–1.37) | 0.95 (0.70–1.30) | 0.93    |
| Seafood dietary pattern         | 1.00             | 1.18 (0.87–1.59) | 1.13 (0.84–1.54) | 1.18 (0.87–1.59) | 0.86 (0.63–1.18) | 0.40    |
| Westernized breakfast pattern   | 1.00             | 1.13 (0.84–1.50) | 1.24 (0.93–1.65) | 1.03 (0.77–1.38) | 0.64 (0.46–0.90) | 0.02    |

Adjusted for age (years), BMI (20.0, 20.1–22.4, 22.5, 22.5–24.9, or ≥25.0 kg/m²), smoking (lifetime nonsmoker, former smoker, or current smoker with a consumption of <20 or ≥20 cigarettes/day), alcohol consumption (nondrinker, former drinker, and current drinker with a consumption of <30, 30–59, or ≥60 g ethanol/day), physical activity (quartile of MET hours/week), and parental history of diabetes (absent or present). *Based on multiple logistic regression analysis, assigning ordinal numbers 0–4 to quintile categories of each dietary pattern.

foods such as butter, milk, and cheese that have relatively high fat contents, which probably reduces the overall glycemic index of the diet. Therefore, a lower glycemic impact of a bread-based breakfast compared with a rice-based one could be an explanation for the decreased A1C concentrations among individuals with a higher score for this dietary pattern. The inverse association with this pattern may also be ascribed in part to frequent intake of coffee, a beverage consistently associated with lower risk of type 2 diabetes (24).

The seafood dietary pattern, characterized by frequent consumption of shellfish, salted fish guts, and fish paste products, was related to a higher prevalence of type 2 diabetes despite their relatively lean body mass. The present cross-sectional associations must be confirmed in prospective studies, and the underlying mechanisms need be clarified.

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