ORIGINAL CONTRIBUTION

Quantitative Identification of Sodium Chloride Sources in Japanese Diet by 24-hour Total Food Duplicate Analysis

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Major source of NaCl among Japanese diet were quantified. Adult inhabitants (1334 subjects, or 499 men and 835 women at the ages of 20 to 70 years) in 49 regions (mostly agricultural) all over Japan offered 24-hour total food duplicates in winter seasons. Sodium chloride (NaCl) contents in each food items in the duplicates were estimated by the weight taking advantage of the Standard Tables of Food Compositions with assumption that sodium is totally attributable to NaCl. The NaCl contents in the duplicates distributed essentially normally with a mean of 14.4 g and a standard deviation of 6.1 g. High NaCl intake was associated with the consumption of pulses, fish/shellfish and vegetables in addition to seasoning/spices. Further analysis showed that *miso* paste, soy bean sauce and pickles accounted for 23.6, 18.8 and 16.7% of total NaCl intake, respectively, or almost 60% when the three items are combined. Multiple regression analysis also indicated that *miso* paste has the strongest influence on total NaCl intake. Of particular interest was the fact that consumption of pickles increased markedly as a function of higher salt intake, from 0.1 g (in terms of NaCl content) among low NaCl consumers (taking < 5 g NaCl/day) to 7.0 g among high NaCl consumers (with ≥ 30 g NaCl/day). *J Epidemiol*, 1993; 3: 77-82.

sodium chloride, Japanese diet, *miso* paste, pickles, salted fish, soy bean sauce

Since the pioneer works by Sasaki et al.¹⁾ and Dahl²⁾, it is well established that, whereas sodium chloride (to be abbreviated as NaCl) is essential for human life, its excess intake will increase the risk of hypertension and resultingly stroke^{3,4)}. Stroke has been the leading cause of death until 1980 when this position was taken by malignant neoplasms in the next year⁵⁾.

A number of studies⁶⁻⁸⁾ have been conducted in various localities especially in north-eastern Japan (where the NaCl intake is known to be high⁴⁾) to report that NaCl intake by the local people at the time of study was usually in excess of 10 g/day, or even as high as 20 g/day. Higher salt intake by rural inhabitants rather than people in urban areas is not limited to Japan but has been reported also from Shanghai, China⁹⁾.

Accordingly, efforts have been made to reduce NaCl intake among the general population with rewarding results⁶⁻⁸⁾. In such studies, *miso* paste (or fermented mixture of soy bean and rice in the presence of NaCl) and pickles (or salted fermented vegetables) in addition to *shoyu* (or soy bean sauce) have been suspected as the major sources of NaCl among traditional Japanese diet. This suspicion is however based on experiences and not yet sufficiently supported by scientific data nor the relative weight among the suspects well quantified.

Efforts are made in the present study to make quantitative evaluation of these food items and to determine their relative importance as NaCl sources for general Japanese population.

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MATERIALS AND METHODS

Collection of 24-hour total food duplicate samples

Strategy of 24-hour total food duplicate collection has been previously described^{10,11}. In short, a whole of three meals, any snack, and drink (both soft and alcoholic) as much as taken by an individual in a given 24-hour period¹² were reserved in acid-washed (metal leakage-free) plastic containers. The sum makes one 24-hour food duplicate sample of the person. Such samples were collected in winter seasons in 1977-1981 from 1334 adult inhabitants (499 men and 835 women at the ages of 20 to 70 years) in 49 regions (mostly agricultural villages) all over Japan.

Estimation of NaCl contents in each 24-hour food duplicate

Each food component in the duplicate from one individual was isolated, weighed (weight being recorded) and identified by its code number given in the Standard Tables of Food Compositions in Japan¹³. The Tables gives the amount of energy and nutrients (including sodium)/unit weight of about 1500 (and therefore almost all) food items taken in Japanese diet, and NaCl amount in each food items and thereby in one 24-hour food duplicate was calculated in a personal computer from the weight, taking advantage of the values given in the Tables. When necessary (e.g., in the case of use of soy bean sauce as a dip for fresh fish meat 'sashimi'), the best estimates for the amounts of seasonings consumed were figured out by one veteran nutritionist throughout the study. For calculation, it was assumed that whole sodium (molecular weight; 22.99) is taken in the form of NaCl (molecular weight; 58.45) and that the amounts of other sodium salts (e.g., sodium glutamate) are negligible.

Statistical analysis

Analysis of variance (ANOVA) was employed when necessary. Multiple regression analysis was applied by both step-up and step-down procedures with a *p* value of 0.01.

RESULTS

Distribution of NaCl intake

When the amount of daily NaCl intake by the 1334 subjects were classified by 5 g range, the distribution appeared to be essentially symmetric with a very slight tailing towards a higher value (Figure 1). Accordingly, a normal distribution was assumed for the distribution in agreement with a previous publication⁴, and arithmetic mean (AM) and arithmetic standard deviation (ASD) were taken as parameters to represent the distribution.

Figure 1. Distribution of daily NaCl intake. A distribution of NaCl by the 1334 subjects is shown. The value on the horizontal axis are medians for 5 g range except for that for the right-most column which is for 35 g/day or more.

tion (ASD) were taken as parameters to represent the distribution. The observation showed that the average daily NaCl intake among the population studied was 14.4 g with ASD of 6.1 g. A coefficient of variation of 42% is not only in an agreement with the assumption of normal distribution, but may suggest rather wide variation among the study population.

Energy and NaCl intake by age and by sex

The distribution of the ages of the whole subjects as classified by the decade of age and by sex showed that a majority of the subjects studied were at the ages of 40s and 50s both in men and women (Table 1). When those at these two decades were combined, the combination accounted for almost 70% of the whole population. Men took more energy and NaCl than women in most age groups. Comparison of energy intake among age groups suggested that men and women at the ages of over 60 years tended to take less energy/day ($P < 0.01$ for both by ANOVA). A similar analysis in NaCl intake suggested that the youngest groups in addition to the oldest tended to take fewer NaCl than other age groups ($P > 0.05$ for men and $P < 0.01$ for women by ANOVA). Regression analysis on individual basis made it clear that, in both sexes, NaCl intake correlated significantly with daily energy intake ($P < 0.01$) but not with age ($P > 0.05$), whereas energy intake less significantly correlated with age with a larger *p* value ($P < 0.05$). Multiple regression analysis with age and energy intake as two independent variables and NaCl intake as a dependent variable made it clear that energy intake explained 17.5% and 22.4% of variation in NaCl intake in men and in women, respectively, whereas the effect of age was nil ($< 0.01\%$) in either

Table 1. Energy and NaCl intake by age and by sex.

Age range (years)	Men			Women		
	No. (%)	Energy ^a	NaCl ^b	No. (%)	Energy ^a	NaCl ^b
20 to 29	34 (6.8%)	2969±976	14.8±7.1	48 (5.7%)	2230±543**	13.0±4.9
30 to 39	90 (18.0%)	2844±683	14.9±6.5	180 (21.6%)	2221±531**	14.3±5.1
40 to 49	141 (28.3%)	2890±656	14.6±5.7	303 (36.3%)	2316±587**	14.5±6.3
50 to 59	177 (35.5%)	2912±743	15.9±7.1	260 (31.1%)	2185±570**	14.3±5.8**
60 & over	57 (11.4%)	2525±700	13.9±4.7	44 (5.3%)	1955±556**	10.5±4.7**
Total	499 (100%)	2853±733	15.0±6.4	835 (100%)	2231±572**	14.1±5.8**

The asterisks show significant difference from male values of the same age (** for $P < 0.01$). ANOVA shows that energy intake is not uniform in both sexes ($P < 0.01$ for both). NaCl intake is uniform in men ($P > 0.05$) but not in women ($P < 0.01$).

^a AM±ASD in kcal/day. ^b AM±ASD in g/day.

sex.

NaCl intake by food group

Food items in each food duplicate were classified by food group of e.g., cereals, potatoes, meat, etc. after Resources Council¹³⁾ and major NaCl sources were identified among the 1334 food duplicates. Calculation with simple assumption of normal distribution showed that ASDs were larger than corresponding

AMs in many cases suggesting that the normal assumption was not applicable. Accordingly, the distribution was expressed also by means of medians in addition to AM and ASD (Table 2).

The calculation indicated that pulses (27.2% when the median was taken), vegetables (18.7%) and fish/shellfish (10.8%) were leading sources in addition to the seasonings per se (38.8%). Because *miso* paste and pickles were classified in the food groups of pulses and

Table 2. NaCl intake by food group.

Food group ^a	NaCl intake (mg/day) ^b			
	Mean±SD	(%)	Median	(%)
G 1. Cereals	385±1227	(2.7%)	65.8	(0.7%)
G 2. Potatoes and starches	9±25	(0.1%)	3.8	(0.0%)
G 3. Sugars and sweeteners	1±4	(0.0%)	0.4	(0.0%)
G 4. Confectioneries	211±306	(1.5%)	88.9	(0.9%)
G 5. Fats and oils	7±38	(0.0%)	0.0	(0.0%)
G 6. Nuts and seeds	4±30	(0.0%)	0.0	(0.0%)
G 7. Pulses	3376±2550	(23.4%)	2753.0	(27.2%)
G 8. Fish and shellfish	1682±1814	(11.7%)	1072.7	(10.8%)
G 9. Meats	339±640	(2.3%)	53.8	(0.5%)
G10. Eggs	236±314	(1.6%)	148.6	(1.5%)
G11. Milks	168±283	(1.2%)	0.0	(0.0%)
G12. Vegetables	2520±2535	(17.5%)	1802.5	(18.7%)
G13. Fruits	290±768	(2.0%)	5.7	(0.1%)
G14. Fungi	6±85	(0.0%)	0.0	(0.0%)
G15. Algae	614±1245	(4.3%)	58.4	(0.6%)
G16. Beverages	42±131	(0.3%)	24.7	(0.3%)
G17. Seasonings and spices	4460±2942	(31.0%)	3928.9	(38.8%)
G18. Prepared foods	96±332	(0.7%)	0.0	(0.0%)

^a Terminology and classification after Resources Council¹³⁾.

^b Calculation based on 1334 cases.

Table 3. Multiple regression analysis with food group as NaCl sources.

Independent variable	F value (P value)	Partial correlation coefficient
G 1. Cereals	0.6 (0.456)	0.043
G 7. Pulses	20.1 (<0.01)	0.252
G 8. Fish and shellfish	51.9 (<0.01)	0.386
G12. Vegetables	62.9 (<0.01)	0.419
G15. Algae	25.0 (<0.01)	0.279
G17. Seasonings and spices	67.5 (<0.01)	0.431

Calculation is based on 306 cases of 40-49 year-old women. Multiple correlation coefficient is 0.733. The dependent variable is daily NaCl intake.

vegetables, NaCl in the two groups, and food items of *miso* paste and pickles were calculated separately. The calculation showed that, in fact, *miso* paste accounted for $99.2\% \pm 4\%$ ($AM \pm ASD$) of NaCl in the pulses group, and pickles for $94.7\% \pm 9.6\%$ of NaCl in the vegetables. A majority ($88.9\% \pm 18.1\%$) of NaCl in the seasonings are from soy bean sauce and table salt.

Women at the ages of 40-49 years were selected for multiple regression analysis of food groups for major NaCl source excluding the effects of age and sex, because this group had the largest population (Table 1). Five major NaCl sources by food group of pulses, fish & shellfish, vegetables, algae, and seasonings & spices (Table 2) together with cereals were selected as dependent variables to explain the variation in NaCl intake. Calculation showed (Table 3) that the 5 groups but cereals were adopted with enough large F values and small p values. Step-up and step-down analysis gave the same results. The multiple correlation coefficient obtained by the step-down method with 6 variables was 0.733. Further calculation with the 5 groups and excluding cereals gave essentially the same value of 0.732, indicating the 5 groups in combination could explain only 54% of total variation. Calculation with those in other age groups or of the other sex gave the same results in identifying the 5 groups as the most influential variables, except that cereals took the place of vegetables in the case of >60 year-old women.

Weight of miso paste, soy bean sauce, and pickles as NaCl sources

Based on the observation on the food groups for major NaCl sources suggesting that *miso* paste, soy bean sauce and pickles may carry considerable weight, a further effort was made to determine the relative weight of these food items as opportunity of taking NaCl through daily food. Calculation of NaCl intake through these food items showed that *miso*

paste, soy bean sauce and pickles accounted for 23.6%, 18.8% and 16.7% of daily intake of 14.4 g as an average for the 1334 cases (the 'Total' line in bottom of Table 4); the sum of the three items was as large as 59% of the total intake. Additional major sources were 'other food items'. Although this category was only poorly defined, search of the menus disclosed the most affecting food items in the category included dried salted fish (e.g., salmon containing 8.1 g NaCl/100 g), fish sausage (2.5 g NaCl/100 g) and cooked preserved seaweed (10.2 g NaCl/100 g) (the contents after Resources Council¹³⁾).

Further classification of the subjects by the amount of NaCl intake (Table 4) showed that the NaCl intake via these food items increased as a function of an increase in total daily NaCl intake, regardless of food items studied. Whereas account for *miso* paste (20 to 24% in most cases) and that for table salt (7 to 9%) stayed rather constant independent of total NaCl intake, relative weight of soy bean sauce and 'other' food items appeared to be reduced at higher NaCl intake. In a sharp contrast, the account for pickles showed a remarkable increase of 3% in the ≤ 5 g/day group to 21% in the 25-30 g/day group.

It was previously observed that men take more NaCl than women of the same region¹⁴⁾. The present study also confirmed that men tended to take more NaCl than women of the same age (Table 1). This is possibly because men take more rice (which is essentially salt-free) than women¹⁴⁾. Accordingly, it was considered possible that the NaCl intake pattern might be different between the two sexes. Analysis with 499 men alone and 835 women alone, however, showed that the results summarized in Table 4 (i.e., results with men and women in combination) were essentially reproducible when calculated with men alone and with women alone.

In order to evaluate further the relative weight of *miso* paste, soy bean sauce and pickles, multiple regres-

Table 4. NaCl sources by the amount of daily NaCl intake.

NaCl intake (g/day)	No. ^a	NaCl intake (g/day) by sources					
		Seasonings				Pickles	Other food items
		Miso paste	SBS ^b	Table salt	Others		
0-≤ 5	30	1.2±0.8 (31.7%)	0.7±0.7 (18.4%)	0.3±0.5 (7.9%)	0.1±0.2 (2.6%)	0.1±0.2 (2.6%)	1.4±0.8 (36.8%)
5-≤10	274	1.6±1.1 (20.3%)	1.8±1.1 (22.8%)	0.7±0.9 (8.8%)	0.3±0.5 (3.8%)	0.9±1.1 (11.4%)	2.6±1.4 (32.9%)
10-≤15	471	2.9±1.8 (23.4%)	2.5±1.5 (20.2%)	1.0±1.2 (8.1%)	0.6±1.2 (4.8%)	1.8±1.6 (14.5%)	3.9±1.9 (29.0%)
15-≤20	349	4.2±2.3 (24.7%)	3.1±1.6 (18.2%)	1.3±1.5 (7.7%)	0.7±1.6 (4.1%)	3.2±2.4 (18.8%)	4.8±2.5 (26.5%)
20-≤25	143	5.2±2.8 (23.6%)	3.7±2.0 (16.8%)	1.6±1.9 (7.3%)	1.0±2.4 (4.6%)	4.1±2.7 (18.6%)	6.4±3.2 (29.1%)
25-≤30	45	6.5±3.0 (23.7%)	3.6±2.3 (13.1%)	2.6±4.1 (9.5%)	0.9±2.2 (3.3%)	5.6±3.5 (20.5%)	8.2±4.0 (29.9%)
30 & over	22	8.0±5.6 (22.0%)	4.6±6.1 (12.8%)	3.0±4.7 (8.4%)	3.6±8.4 (9.9%)	7.0±6.4 (19.1%)	10.1±7.2 (27.8%)
Total	1334	3.4±2.5 (23.6%)	2.7±1.9 (18.8%)	1.2±1.7 (8.3%)	0.6±1.8 (4.2%)	2.4±2.5 (16.7%)	4.1±2.9 (28.5%)

The values in the tables are intake of NaCl (arithmetic mean±arithmetic standard deviation in g/day) followed by the portion (in % in parenthesis) among the daily intake from all sources.

^a Number of subjects in the category.

^b Soy bean sauce.

sion analysis was conducted with 303 cases of 40-49 year-old women excluding possible effects of age and sex. Calculation with *miso* paste, soy bean sauce and pickles either in combination or separately showed that the 3 items in combination could explain 64.6% of total variation, whereas *miso* paste alone, soy bean sauce alone and pickles alone explained 46.4%, 24.3% and 29.1%, respectively. The results suggest that *miso* paste is the most influential among the three, and that the roles of other foods cannot be ignored, in agreement with the observation in Table 4.

DISCUSSION

There are several approaches in estimating daily NaCl intake¹²⁾. In the present study, 24-hour total food duplicate analysis was employed because this approach allows allocation of NaCl burden to each food component, and a value of 14.4 g/day was obtained as AM for 1334 participants who were mostly farmers. The value is apparently very close to the result of National Nutrition Survey 1980 reporting 14.7 g/day as a daily intake by farmers¹⁴⁾; National Nutrition Survey took advantage of the amounts of food items consumed in a given period of three days by members of a family in concern¹⁵⁾.

It is well known that the excess NaCl is a risk factor of hypertension and subsequently of stroke¹⁻⁴⁾, and

efforts have been made to reduce NaCl intake to a recommended level of 5 g/day³⁾ or 10 g/day at most¹⁶⁾. In a public campaign against high salt intake¹⁶⁾, intake of fresh vegetables, use of acid taste in place of saltiness, care towards NaCl contents in prepared food, etc. are advocated. In a rural area, the wording employed was more frank by saying 'avoid salty *miso* soup and eat less pickles'¹⁷⁾. Counterpart words in Europe were 'ban the salt cellar from table, avoid the use of salt during food cooking at home, and purchase only foodstuffs without added salt'¹⁸⁾, or 'add less salt in the kitchen, eat less cod fish and fewer sausages, and add less salt when baking bread'¹⁹⁾. It is clear from these words of appeals that there exist marked regional difference in the sources of NaCl in daily food.

The present study clearly demonstrated that three food items of *miso* paste, soy bean sauce and pickles are in fact three leading sources of NaCl intake among Japanese population especially farmers who were more traditional in food habits than urban residents. On an average, the three food items in combination accounts for almost 60% of total NaCl intake (Table 4), although other sources such as dried salted fish and preserved seaweed cannot be ignored as NaCl sources. The results offer quantitative basis of taking these food items as target of anti high-salt campaign. To the knowledge of the authors, there has been no similar analysis in the past except that Omura et al.²⁰⁾ counted

these food items (in addition to other 5 items) among those showing positive relation with increased standardized ratios for mortality from cerebrovascular diseases.

Of particular interest is the fact that high-salt eaters used to take more pickles than proportional to their NaCl intake. Experiences in rural areas show that farmers have custom of taking pickles not only at the time of meal but at tea break time e.g. in place of cookies. Pickles are among the most readily available food of wide acceptance in rural areas with low cost for production. Technique should be developed for preparing low-salt pickles by better control of fermentation process, rather than simple suppression of the consumption, as was the case of effort to reduce salt content in *miso* paste²¹⁾ which is another typical fermentation product among traditional Japanese food items.

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