A Validation Study on a Method to Estimate Nutrient Intake by Family Members through a Household-based Food-weighing Survey

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(Received September 28, 2000)

Summary The aim of the present study is to investigate the validity of a new method to estimate the food intake of individual subjects by a household-based dietary survey. The new method is based on the combination of household-based food weighing and approximating the proportions by which family members shared each dish or food in the household, which has been one of the components of the National Nutrition Survey, Japan, since 1995. We analyzed two sets of data from 64 volunteers (female students taking a dietitian course and their mothers) in 32 households by the approximated proportion method (method A) and the individual-based food weighing method (B) as a reference measurement. Energy and macronutrient intake by individual subjects estimated by method A was highly correlated to the corresponding values by method B (Pearson’s correlation coefficients; r=0.90-0.92). Average energy intake was likely to be underestimated by method A compared with method B, being lower by 94 kcal (6.2% of the reference value in method B), at least in the young and middle-aged female adults that were the subjects of this study. When intake of boiled rice was separately analyzed, underestimation of energy intake by method A was 44 kcal, which contributed to approximately 50% of the total magnitude of the underestimation. The procedure manual for the National Nutrition Survey requests the participants to individually weigh the amount of boiled rice taken by family members in the household. However, this procedure is not observed in many actual settings. Therefore, following this procedure would be an effective measure to improve the accuracy of the dietary data.

Key Words dietary survey, food weighing method, individual-based survey, validation, bias

The dietary survey is a core component of nationwide nutrition monitoring (1), including the National Nutrition Survey, Japan (NNS-J). The NNS-J was initiated in 1946 with the main purpose of obtaining basic information for emergency food supplies from other countries (2). Thus, household-based food consumption data had been conventionally collected from the standpoint of food security. The aim of the survey, however, has shifted from food supply issues to chronic disease prevention, and individual-based dietary data have become essential to clarify diet-disease relationships.

A new method (hereinafter called the approximated proportion method) to estimate the food intake of individual subjects in a household has been used in the NNS-J since 1995. This method is based on a combination of household-based food weighing and an approximation of proportions by which family members shared each dish or kind of food in the household (3, 4) (Fig. 1). This hybrid method was adopted by the NNS-J because it was expected to allow comparisons with dietary data that had been conventionally collected for more than 50 years by the household-based food weighing method.

The aim of the study is to investigate the validity of the new method to estimate the amount of food intake of individual subjects in a household-based dietary survey by comparing corresponding values from the individual-based food weighing method as a reference method.

METHODS

1) Subjects and settings. We recruited female volunteers who were taking the diploma course for dietitians at a college in Osaka and Miyagi, respectively. Eligible subjects were 32 students (hereinafter called students) who were living with their families and 32 persons who prepared their meals at home (hereinafter called 'cooks' and who were the mothers of the students). All agreed to participate in this trial.

We had a half-day class in which students were taught to accurately weigh and record the amount of food consumed by individual members who shared the
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Fig. 1. A dietary recording sheet for estimating individual food intake. (Ministry of Health and Welfare. 2000. Annual report of the National Nutrition Survey in 1998, Daiichi Publishing Co., Tokyo).*1 Survey participants are requested to individually weigh the boiled rice taken by family members.

*2 In many actual settings, participants do not individually weigh the boiled rice and just approximate the proportions of sharing.

*3 The proportions by which the individual family members share each dish or food will be expressed as a combination of simple integers.

dishes served at a large table in the usual household setting. We explained the procedure and instructed cooks on the method of household-based food weighing and approximating the proportions of food sharing, which was basically same procedure as in the NNS-J. To avoid possible bias due to behavioral changes, we did not inform the cooks about the aim of the trial. Actual data collection was done on a selected day including weekends and holidays.

2) Dietary survey. The cooks weighed and recorded all the ingredients used for cooking in the household and tried to approximate the proportions by which the family members shared each dish or food in the household according the procedure manual used in the NNS-J with some modifications for the specific purposes of our study. Although the procedure manual of the NNS-J requested the participants to individually weigh the amount of boiled rice the family members actually ate (Fig. 1; *1), we instructed the cooks only to approximate the proportion of boiled rice consumed by the family members in this trial (Fig. 1; *2), because we found that only 35.1% (112/356) of the participants in a subsample of the NNS-J actually weighed the boiled rice. The type and amount of food eaten outside the home was also recorded for each member of the family by the cook. On the other hand, the students weighed and recorded the total amount of dishes, the amount actually eaten by the cooks and themselves, and the amount of food except for meals taken outside the home. Data obtained by the cooks and the students were independently recorded to prevent overlapping between the two methods.

3) Data analyses. We referred to the method that was performed by the cooks (approximated proportion method) as method A and the individual-based food weighing method that was performed by the students as method B, being the reference method. The approximated proportions by which a selected dish was shared by the family members or was leftover, being recorded as the combination of simple integers or common fractions on the recording sheet (Fig. 1; *3), will be converted in percentages to a1, a2,...,ai, aleft (a1: proportion for the cook, a2: proportion for the student, ai: proportion for the ith family member, aleft: proportion for the leftovers (%); a1+a2+...+ai+aleft=100%). The total amount of each dish or food consumed in the household including leftovers will be multiplied by a1/100 and a2/100, giving the estimated amounts consumed.
Table 1. The mean values of energy and macronutrients intake calculated by the approximated proportion method (method A) and the individual-based food weighing method (method B).

|                | method A          | method B         | Difference between methods A and B | % of the reference value*1 | p value*2 |
|----------------|-------------------|------------------|-----------------------------------|---------------------------|----------|
|                | mean±SD           | mean±SD          | $A-B$ (SE)                        |                           |          |
| Energy (kcal)  | 1,411±499         | 1,505±498        | -94 (26)                          | 6.2%                      | <0.001   |
| Protein (g)    | 63.3±22.9         | 67.2±24.3        | -3.8 (1.2)                        | 5.7%                      | 0.002    |
| Fat (g)        | 41.9±18.6         | 44.9±21.4        | -3.0 (1.1)                        | 6.7%                      | 0.007    |
| Carbohydrate (g)| 187.9±78.9     | 200.5±75.7       | -12.6 (4.4)                       | 6.3%                      | 0.005    |

*1 Calculated as $(A-B)/B\times100\%$. *2 by paired t-test.

by the cooks and the students, respectively. We calculated energy and macronutrient intake for the 32 cooks and 32 students from the two data sets by methods A and B, using the same food composition table as used in the NNS-J.

We first investigated the difference in mean values of energy and macronutrient intake between the methods by paired-t test, which may lead to systematic bias in population data. Secondary Pearson’s correlation coefficients between the methods with log-transformed data to improve the normality were computed in order to validate method A by referring to method B (5). Because the correlation coefficients may not be appropriate indicators for the agreement between the methods (6), a general linear model was adopted with the reference values by method B as dependent variables and the observed values by method A as independent variables to determine a regression line. Thereafter the differences in energy intake between the two methods were depicted against the average values by the two methods in order to observe the tendencies toward systematic bias (6). Finally boiled rice and Japanese-style soups (e.g., miso soup, clear soup, and other types of traditional-style soup) were separately analyzed as typical Japanese dishes to investigate the major error sources in energy intake.

RESULTS
1) Mean values of energy and macronutrient intake by methods A and B (Table 1)
The mean energy intake calculated by method A was 1,411 kcal, which was lower than the corresponding value (1,505 kcal) by method B (6.2% of the reference value by method B). The tendency toward underestimation was also observed for protein, fat, and carbohydrate intake with differences of $-3.8\ g$ ($5.7\%$), $-3.0\ g$ ($6.7\%$), and $-12.6\ g$ ($6.3\%$ of the reference value by method B), respectively. All differences between the two methods were statistically significant. The regression coefficients ($\beta$) for the values by method A to predict the reference values by method B were 0.91, 0.97, 1.06, and 0.86 for total energy, protein, fat, and carbohydrate, respectively. However, only the value for carbohydrate was significantly lower than 1.0. All the values for intercept in the linear models were positive, being statistically significant only for energy and carbohydrate intake.

2) Correlation and regression for energy and macronutrient intake between methods A and B (Table 2, Fig. 2)
Pearson’s correlation coefficients between the values by methods A and B were 0.90, 0.89, 0.91, and 0.90 for total energy, protein, fat, and carbohydrate, respectively. These relationships between the two methods were all statistically significant. The regression coefficients ($\beta$) for the values by method A to predict the reference values by method B were 0.91, 0.97, 1.06, and 0.86 for total energy, protein, fat, and carbohydrate, respectively. However, only the value for carbohydrate was significantly lower than 1.0. All the values for intercept in the linear models were positive, being statistically significant only for energy and carbohydrate intake.

DISCUSSION
1) Dietary survey methods for nation-wide nutrition surveys
There have been many discussions on appropriate methods of dietary surveys (7) especially for large-scale population-based studies. The 24-hour recall method has been used in a nationwide nutrition survey in the United States (8) and Canada (9). Other methods to determine the intake of individual subjects, such as estimated food intake records or a semi-quantitative food frequency questionnaire, have been used in European countries (10, 11).

In contrast, food consumption surveys in the household as a unit mainly utilizing the weighed-food recording method have been used mostly in East Asian countries such as the Republic of Korea (12), China (13), and Japan (2). In these countries, meals are usually...
Table 2. The correlation and regression for energy and macronutrients intake by the approximated proportion method (method A) and the individual-based food weighing method (method B).

|          | Pearson's correlation | Regression (B=β×A+Intercept)*2 |
|----------|-----------------------|---------------------------------|
|          | Correlation coefficient (r)*1 | p value | β (SE) | Intercept (SE) | F value |
| Energy (kcal) | 0.90 | <0.001 | 0.91 (0.052) | 219.5 (77.3) | 310.5 |
| Protein (g)    | 0.89 | <0.001 | 0.97 (0.053) | 5.57 (3.53)  | 343.2 |
| Fat (g)         | 0.91 | <0.001 | 1.06 (0.058) | 0.51 (2.66)  | 332.2 |
| Carbohydrate (g)| 0.90 | <0.001 | 0.86 (0.053) | 38.3 (10.8)  | 262.4 |

*1 Pearsons’ correlation coefficient after log transformation of the variables.

*2 The values from method B were used as dependent variable and the values from method A as independent variables in a regression model.

Fig. 2. Regression analyses on measure by method A against reference values by method B.

served from a large dish or large bowl to all members at the table. Individuals place part of the food on their own small plate or eat directly from the large dish or bowl. This manner of eating may make it more difficult to determine the amount of food taken by individual subjects than food consumed by all of the family members.

When the dietary survey method for the NNS-J was changed to obtain individual-based food intake data, the comparability of data that had been collected by the household-based food-weighing method since 1946 was regarded as an issue of highest priority (4). Due to this prioritization by the government and the distinctive manner of eating in Asian countries as already mentioned, the new combinative method was developed for
2) Correlation and agreement between the new method and the reference method

Results of this validation study indicated high correlation coefficients between the new method (method A) and the individual-based food-weighing method (method B), which were approximately 0.90 for total energy and macronutrients (Table 2). This suggested that inter-individual variability could be measured by method A as well as by method B, but did not mean good agreement between the two methods. The statistically significant negative difference between method A and B ($A - B$) for energy and all the macronutrients (Table 1), and positive values of the increment for energy and carbohydrate intake (Table 2) will also indicate that the new method is likely to underestimate food intake, at least, in the young and middle-aged female adults participating in this study. This systematic bias (underestimation) for energy intake seemed independent of the measurement values expressed by average figures by the two methods (Fig. 3).

3) Error sources for underestimation of energy intake by the new method

Possible error sources for underestimation would be mainly due to the difficulty in approximating the proportions of food shared, especially in the case of dishes served from a large plate or bowl. In contrast, the amount of food taken outside the home could not be actually measured, although the kind and number of meals with some information on portion size was recorded, and the approximated proportion method was used even in method B, which means that no discrepancies would occur for meals taken outside the home in this study design. Differences between results from methods A and B could be attenuated if the proportion of the meals taken outside the home were quite large in relation to the entire dietary data. Dietary data in this study included only 41 dishes that were taken outside the home, while the total number of dishes was 553. Therefore, the influence of outside eating on study results is thought to be small. Among the dishes taken at home, the frequency of boiled rice was high and its con-
tribution to total energy was large (23%). As already mentioned, the procedure manual for the NNS-J requests the participants to individually weigh the amount of boiled rice taken by household members (individual-based food weighing) as the only exception to the approximated proportion method. However, this procedure does not seem to be followed in many settings.

To investigate the influence of this problem, we instructed the cooks to deal with the boiled rice in the same manner as with the other dishes, that is, without weighing it in this study. When the intake of boiled rice was separately analyzed, underestimation of energy intake by method A contributed to as much as half of the total magnitude of the underestimation (Fig. 4). Therefore, if the boiled rice taken by the family members at home was individually weighed by following the procedure of the NNS-J, the accuracy of the dietary data could be much improved.

4) Limitation in a study sample

Generally it is desirable to use a sample similar to the target population for the actual survey. In this case the NNS-J, for the purpose of a validation study on the survey method. We selected the students, who were females around 20 years of age, and the cooks, who were students’ mothers with a mean age of 48.6 years as study subjects only because of feasibility in completing this trial that required complicated procedures and constituted a burden both for cooks and observers. For this reason the study setting might have caused some bias in results. However, the main purpose of this study is to assess the ability of the cooks to approximate the proportions of food shared in a household including its methodological issues. Therefore, the characteristics of the cooks (=student’s mothers) as a study sample would be more important than the characteristics of students themselves that are apparently different from the general population.

The underestimation observed in method A would be due not only to methodological reasons, but might also result from the characteristics of the target subjects (young and middle-aged female adults), who are thought to have a small food intake compared with other family members such as middle-aged men (students’ fathers) or young men (students’ brothers) (3). It would be a more appropriate study design, if we had included other family members as target subjects. However, we could not do it because of the feasibility of this trial. For the several reasons mentioned above, we should be very careful to interpret the results, especially when extrapolating them to general issues in the NNS-J.

Regarding the perception of food intake in the subjects of a dietary survey, several trials have been done in western societies using food portion size (14, 15). A well-designed British study reported that age, sex, body mass index of the subjects and portion size itself could be important confounders when estimating nutrient intake by use of photographs (14). Although that study used an individual-based dietary assessment method, being much different from the setting in our study, such systematic approaches to determine possible error sources or confounders for estimating food intake are also important to clarify some key issues in our settings.

Acknowledgment

This work was supported by a Grant-in-Aid (“A study on methodological issues of the National Nutrition Survey”; principal investigator: Nobuo Yoshiike) for Health Science Research from the Ministry of Health and Welfare of Japan. We would like to thank Miss Yukako Obazawa, Miss Chiaki Takahashi and Mrs. Kimiko Ichimura for their assistance in data management.

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