Validation of Food-Frequency Questionnaires for Polyphenol Intake in Japanese Adults

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Summary Estimations of individuals’ polyphenol intake contributes to the understanding of the health benefits of dietary polyphenol. We developed a food frequency questionnaire for polyphenol intake (FFQ) and a short-form FFQ for polyphenol intake (SF-FFQ) for assessing the polyphenol intake of Japanese. The aim of this study was to compare the relative validity of polyphenol intake derived from the FFQ with that from the SF-FFQ, using a 4-consecutive-d dietary record (DR) as the reference. Sixty Japanese subjects aged 30–69 y completed the 4-d DR and the two FFQs regarding their polyphenol intake in November 2019. The polyphenol intake values estimated by the DR, FFQ, and SF-FFQ were 1,057 ± 524 mg/d, 1,061 ± 537 mg/d and 1,015 ± 491 mg/d, respectively. No significant differences were present in the estimated polyphenol intake between the 4-d DR and both FFQs. The correlation coefficient with the DR was 0.779 for the FFQ and 0.814 for the SF-FFQ. These results indicate that the total polyphenol intake in a Japanese population were accurately estimated by the FFQ and SF-FFQ.

Key Words polyphenol intake, validation, food-frequency questionnaire, Japan, adult

Polyphenols are present in most foods and beverages of plant origin, and their health benefits have been widely identified (1, 2). Several studies have suggested that polyphenol consumption contributes to a reduction in the risks of chronic diseases (3–5). There are several dietary assessments to estimate total polyphenol intake, e.g., 24-h dietary recall, food-frequency questionnaires (FFQs), and several-day food diaries. It is somewhat burdensome for general populations to complete dietary record (DR) precisely and consistently, but FFQs are easy to answer and are useful for assessing long-term dietary habits. We have developed an original polyphenol content database, and we estimated the total polyphenol intake in several Japanese populations (6–14). We have also developed an original FFQ for polyphenol intake (9, 12) that assesses the consumption frequency of 89 selected foods and beverages and requires approx. 15–20 min to complete. For even easier and quicker evaluations of polyphenol intake, we developed a new short-form FFQ (SF-FFQ) for polyphenol intake that asks the consumption frequency of only 12 foods and beverages. We conducted the present study to compare and validate the polyphenol intakes of Japanese adults as estimated by the FFQ and the SF-FFQ for polyphenol with that obtained by a 4-d DR.

Subjects and Methods

The FFQ and the SF-FFQ for polyphenol intake were our originally developed FFQs that ask the respondent about the consumption frequency of selected foods during the preceding month. The FFQ assesses the consumption frequency of 66 foods and 23 beverages, and the SF-FFQ assesses four foods and eight beverages. The food and beverage items contained in the FFQ and SF-FFQ are significant items that are rich in polyphenols according to our previous studies (6, 7). The FFQ and the SF-FFQ ask for the frequency of intake of each item on a grade of 7 to 11 and 5 to 9, respectively (Table S1 and S2, Supplemental Online Material).

We asked 64 healthy and normal-weight Japanese adults (30 males and 34 females, aged 30–69 y) to complete a 4-consecutive-day DR and the two FFQs in November 2019, and 60 of the subjects (29 males and 31 females) were able to complete all three. The sample size and the number of days required to record the DR were determined based on our previous related study (10). We reported that a group size of 39 was required to estimate a group’s mean polyphenol intake within 20% deviation and that the number of days to require to rank individuals within a group with r=0.9 was 4 d (10).
The DR and the FFQs were checked by trained registered dietitians, and if necessary, the subjects were asked to complete them again or clarify their answers. This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures were approved by the Ethical Committee of Nihonbashi Cardiology Clinic (No. NJI-019-09-02). The study has been registered in the UMIN-CTR as UMIN000038389 (http://www.umin.ac.jp/english/).

Written informed consent for their participation was obtained from all subjects.

For the estimation of dietary total polyphenol intake, we used our original database of the polyphenol content of foods available in Japan. The total polyphenol content in each food and beverage was measured by a modified Folin-Ciocalteu method using reverse-phase column chromatography to remove the interference by nonpolyphenol compounds. We calculated the daily polyphenol intake by matching the food consumption data from each subject who completed the DR and both FFQs with the polyphenol content database on foods and beverages. In the SF-FFQ, the total polyphenol intake was calculated in increments of 50 mg from the frequency of intake of each item. The subjects’ daily intakes of energy and nutrients were calculated from the 4-d DR on the basis of the 2015 Standard Tables of Food Composition in Japan.

The resulting data are expressed as the mean±standard deviation (SD) or the median and IQR (interquartile range). Spearman’s correlation coefficients were calculated to assess the relationships between the DR and the FFQs. The percentage differences obtained between each of the FFQs and the DR were calculated using the

Table 1. Characteristics of the 60 subjects.

| Body composition | mean±SD |
|------------------|---------|
| Age years        | 50.3±10.6 |
| Weight kg        | 59.7±9.4 |
| BMI kg/m²        | 22.0±2.2 |
| Daily dietary intake |         |
| Energy kcal      | 1.956±0.477 |
| Protein g        | 69.8±18.3 |
| Fat g            | 62.2±20.1 |
| Carbohydrate g   | 262.0±71.2 |

Table 2. Polyphenol intakes, percentage differences, and Spearman’s correlation coefficients (r) derived from the DR, FFQ, and SF-FFQ.

| Polyphenol intake (mg/d) | Percentage difference (%) | p-value | r  |
|--------------------------|---------------------------|---------|----|
|                          | mean±SD | median | IQR |              |        |     |
| Total (n=60)             |         |        |     |              |        |     |
| DR                       | 1.057±524 | 966    | (653–1.407) | 0   | 0.924 | 0.779 |
| FFQ                      | 1.060±537 | 1.033 | (614–1.398) | -4  | 0.420 | 0.814 |
| SF-FFQ                   | 1.015±491 | 925    | (650–1.275) | -1  | 0.820 | 0.812 |
| Male (n=29)              |         |        |     |              |        |     |
| DR                       | 1.128±605 | 1.124 | (631–1.614) | -6  | 0.325 | 0.817 |
| FFQ                      | 1.116±581 | 1.050 | (674–1.531) | -2  | 0.852 | 0.768 |
| SF-FFQ                   | 1.062±525 | 1.100 | (650–1.300) | 2   | 0.799 | 0.751 |
| Female (n=31)            |         |        |     |              |        |     |
| DR                       | 992±434  | 937    | (670–1.195) | 1   | 0.937 | 0.895 |
| FFQ                      | 1.009±497 | 902  | (614–1.215) | 5   | 0.695 | 0.863 |
| SF-FFQ                   | 971±462  | 900   | (625–1.150) | 5   | 0.695 | 0.863 |
| 30 s (n=12)              |         |        |     |              |        |     |
| DR                       | 785±476  | 823    | (456–946) | 1   | 0.937 | 0.895 |
| FFQ                      | 790±454  | 655    | (470–1.085) | 5   | 0.695 | 0.863 |
| SF-FFQ                   | 825±448  | 700    | (475–1.200) | 5   | 0.695 | 0.863 |
| 50 s (n=15)              |         |        |     |              |        |     |
| DR                       | 1.054±589 | 1.102 | (569–1.503) | 12  | 0.246 | 0.806 |
| FFQ                      | 925±424  | 902    | (571–1.171) | -12 | 0.246 | 0.806 |
| SF-FFQ                   | 882±326  | 950    | (650–1.200) | 16  | 0.136 | 0.751 |
| 60 s (n=16)              |         |        |     |              |        |     |
| DR                       | 1.250±533 | 1.111 | (858–1.677) | 10  | 0.234 | 0.706 |
| FFQ                      | 1.376±573 | 1.203 | (965–1.861) | 3   | 0.642 | 0.896 |
| SF-FFQ                   | 1.291±554 | 1.250 | (800–1.675) | 3   | 0.642 | 0.896 |

DR, dietary record; FFQ, food-frequency questionnaire; SF-FFQ, sort-form food-frequency questionnaire.
following formula: (FFQs−DR)/DR×100 (%). The statistical differences in total polyphenol intake between the DR and each FFQ were determined using the Wilcoxon matched pairs signed-rank test. Values of \( p \leq 0.05 \) were considered significant. All statistical analyses were conducted with IBM SPSS software, ver. 20.

**Results and Discussion**

The characteristics of the 60 subjects are summarized in Table 1. Table 2 provides the mean and median polyphenol intakes derived from the DR, the FFQ, and the SF-FFQ, plus the results of the statistical tests for the assessment of the relative validity. The correlation coefficient with the DR was 0.779 for the FFQ and 0.814 for the SF-FFQ in total, 0.812 for the FFQ and 0.817 for the SF-FFQ in the men, and 0.751 for the FFQ and 0.768 for the SF-FFQ in the women. These results showed that the FFQ and the SF-FFQ had high ranking ability. No significant differences between the DR and the FFQ or between the DR and the SF-FFQ were observed.

The percentage difference between the DR and the FFQ was 0% (total), −1% (men), and 2% (women), and that between the DR and the SF-FFQ was −4% (total), −6% (men), and −2% (women), respectively. The age-specific analysis showed results that were similar to the overall results (Table 2).

The FFQ yields information about 89 food and beverage items, and with the FFQ we can observe how much polyphenols were consumed and which foods and beverages contributed to the total polyphenol intake in detail, but the FFQ takes a long time to complete. The SF-FFQ we developed is simple and it takes shorter time to complete. Furthermore, the SF-FFQ can easily calculate the total polyphenol intake by adding the points applied to each grade of frequency of intake of the listed items. The SF-FFQ yields information about only 12 foods and beverages items that have been shown to be important sources of total polyphenol intake in our previous studies (6–12). We have reported that the top 10 food and beverage items accounted for >80% of the total polyphenol intake, and the top 20 items accounted for >90%, indicating that a limited variety of items could contribute to the dietary polyphenol intake by Japanese (9). Since general FFQs do not have enough questions about these major items, the FFQs we developed may be useful for estimating polyphenol intake easily and appropriately. Our present findings revealed a high correlation of polyphenol intake between the DR and both the FFQ and the SF-FFQ, and both FFQs were shown to be reliable methods to assess the total polyphenol intake in this Japanese population.

There are some limitations in this study. First, the study design was cross-sectional, not population-based, although the number of subjects by sex and age was well balanced. Second, the subjects were limited to individuals living in urban areas. The variety of foods eaten by residents of urban areas in Japan might differ from those consumed by rural residents. It was reported that there was a 1.4-times difference in consumption of beverages, which is a large source of polyphenols, between the largest and smallest regions of Japan (https://www.mhlw.go.jp/content/000615325.pdf). Thirdly, our FFQs for polyphenols were developed for assessing current Japanese diets. Food consumption patterns vary among countries and might change over time. According to recent studies, Japanese consume polyphenols largely from beverages (approx. 80%), and less from vegetables and fruits (<10%) (7, 9–12), whereas vegetables and fruits as well as beverages contribute to polyphenol intake in European countries (15–17), but the situation may change in the future. Thus, the FFQs may be useful only for the present Japanese population. Finally, the dietary assessment was conducted in November, so information in other seasons is lacking. We previously conducted the FFQ four times a year (once in each season) among Japanese university students and reported that no significant difference was found in the total polyphenol intake between the four seasons (12). Therefore, it is assumed that the effect of seasonal differences is not significant, but further studies are needed to determine whether similar results can be obtained in other seasons.

In conclusion, we observed reasonable relative validity of the polyphenol intake of Japanese adults estimated by the FFQ and SF-FFQ compared with those estimated by a 4-d DR. These results support the use of not only the FFQ but also the SF-FFQ for assessing the polyphenol intake in epidemiological studies among Japanese adults.

**Authorship**

Research conception and design: CT, YK and KK; experiments: CT and YK; statistical analysis of the data: CT; interpretation of the data: CT, YK and YF; writing of the manuscript: CT and YK; reviewing of the manuscript: YF and KK.

**Disclosure of state of COI**

The authors declare no conflicts of interest associated with this manuscript.

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**Supporting information**

Supplemental online material is available on J-STAGE.

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