Estimated Dietary Polyphenol Intake and Its Seasonal Variations among Japanese University Students

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(Received July 24, 2018)

Summary The intake of polyphenols among Japanese has been estimated in several adult populations, but there has been no information regarding their intake among young adults, especially in those in their twenties. We conducted a food frequency questionnaire (FFQ)-based dietary assessment four times a year (once in each season) among Japanese university students and evaluated the total polyphenol intake across and within seasons. Forty-nine subjects (aged 20.7±0.6 y) completed our FFQ regarding polyphenol intake in February, May, August, and November 2016. We then calculated their total polyphenol intake using our polyphenol content database. The mean intake of total polyphenol across the seasons was 567±236 mg/d, which was largely sourced from beverages (62%). No significant differences were found in the total polyphenol intake or polyphenol intake from beverages among the four seasons. By contrast, we observed significant seasonal differences in the subjects’ polyphenol intake from food; the polyphenol intake from food in February (255 mg/d) was significantly higher than that in May (215 mg/d), August (187 mg/d) and November (196 mg/d) (p<0.0001). These findings should assist in future estimations of dietary polyphenol intakes that consider differences according to age and season.

Key Words polyphenol intake, university student, seasonal variation, beverage, green tea, coffee, vegetables, fruits, confectionaries

Polyphenols are major compounds present in many plant foods and beverages, such as coffee, teas, vegetables, and fruits (1). We developed an original polyphenol content database and estimated the total polyphenol intake in several Japanese adult populations (2–8). Based on the findings obtained in those studies, we documented that beverages were a larger source of total polyphenol (approx. 80%) than food, and that coffee and green tea were the major sources of dietary polyphenols in Japanese adults. With the use of beverage consumption surveys, we observed that the polyphenol intake from beverages was higher in participants at higher ages (2, 4). We thus suspect that the total polyphenol intake is influenced by age, but there has been no information about the total polyphenol intake among young adults, especially those in their twenties.

We also observed that the polyphenol intake from beverages was high in the winter and low in the summer (4) and that the polyphenol intake from vegetables and fruits (obtained by calculating the data from a Family Income and Expenditure Survey) was highest in the winter and lowest in the summer (6). The total polyphenol intake thus seems to show seasonal changes in food consumption. However, the seasonal variations of total polyphenol intake have not been clarified. In the present study, we evaluated Japanese university students’ polyphenol intake and examined the seasonal variations in their total polyphenol intake.

Subjects and Methods

The study subjects were recruited from among university students who were in a training course for registered dietitians. Fifty-three students aged 19–22 y were enrolled. The sample size was determined based on our previous related study, in which we reported that a group size of 39 was required to estimate a group’s mean polyphenol intake within 20% deviation (7). This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and the study procedures were approved by the Ethics Committee of Ochanomizu University (No. 2015-15) and Toyo University (No. 2015-K-09). Written informed consent to

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participate was obtained from all subjects, and parental consent was required and obtained for minor subjects (<20 y).

Forty-nine subjects completed both our food frequency questionnaire (FFQ) regarding their polyphenol intake and a consecutive-7-d dietary record four times a year, in February (winter), May (spring), August (summer), and November (autumn) 2016. The FFQs and 7-d dietary records were checked by trained registered dietitians, and, if necessary, the subjects were asked to complete them again. The FFQ for polyphenol intake was our originally developed FFQ which assesses the consumption frequency of 66 foods and 23 beverages that are significant items rich in polyphenols according to our previous studies (2, 3).

For the estimation of dietary polyphenol, we used our original database of the polyphenol content; the main values from this database are as described in the previous reports (2, 3, 5). The total polyphenol content in food and beverages was measured using 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 the subjects’ FFQs with the polyphenol content in the foods and beverages. We demonstrated that no significant differences were present in the estimated polyphenol intake between the 7-d dietary record and the FFQ, and positive correlations were found between them (7).

The subjects’ daily intakes of energy and nutrients were calculated from the 7-d dietary records on the basis of the 2015 Standard Tables of Food Composition in Japan.

All data are expressed as means±standard deviation (SD). Seasonal differences in polyphenol intake were tested by a repeated-measures analysis of variance (ANOVA), followed by Bonferroni’s multiple comparison test if applicable. The differences between males and females were tested by unpaired t-test. Values of \( p < 0.05 \) were considered significant. All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 20 (IBM, Tokyo, Japan).

### Table 1. Profile of the 49 university student subjects.

|                  | Total (\( n=49 \)) mean±SD | Male (\( n=17 \)) mean±SD | Female (\( n=32 \)) mean±SD |
|------------------|----------------------------|--------------------------|----------------------------|
| **Body composition** |                            |                          |                            |
| Age y            | 20.7±0.6                   | 20.8±0.7                 | 20.7±0.6                  |
| Weight kg        | 55.3±9.3                   | 63.3±9.5                 | 51.0±5.7**                |
| BMI kg/m²        | 20.8±2.2                   | 21.8±2.9                 | 20.2±1.5                 |
| **Daily dietary intake** |                        |                          |                            |
| Energy kcal      | 1576±390                   | 1789±412                 | 1462±331**                |
| Protein g        | 57.3±16.5                  | 64.8±18.5                | 53.2±14.1*                |
| Fat g            | 50.9±13.4                  | 54.3±14.3                | 49.1±12.7                |
| Carbohydrate g   | 209.7±54.6                 | 245.1±54.9               | 190.8±44.8**              |

*** \( p < 0.001 \), * \( p < 0.05 \) compared to the males by unpaired t-test.

### Table 2. Polyphenol intake from foods and beverages across seasons.

| Polyphenol intake (mg/d) | Total (\( n=49 \)) mean±SD | Male (\( n=17 \)) mean±SD | Female (\( n=32 \)) mean±SD |
|--------------------------|----------------------------|--------------------------|----------------------------|
| Total                    | 567±236                    | 593±214                  | 554±249                    |
| Beverages                | 354±223                    | 398±228                  | 331±220                    |
| Green tea                | 152±172                    | 211±204                  | 121±145                    |
| Coffee                   | 109±135                    | 91±94                    | 119±153                    |
| Other beverages          | 93±88                      | 96±97                    | 91±85                      |
| Foods                    | 214±76                     | 195±64                   | 223±80                     |
| Vegetables               | 66±35                      | 58±28                    | 71±39                      |
| Pulses                   | 43±27                      | 47±27                    | 40±27                      |
| Seasonings and spices    | 25±14                      | 23±11                    | 27±15                      |
| Cereals                  | 25±8                       | 27±7                     | 23±9                       |
| Fruits                   | 24±18                      | 25±18                    | 24±19                      |
| Confectionaries          | 21±22                      | 10±10                    | 27±25***                   |
| Other foods              | 9±7                        | 6±5                      | 10±8                       |

*** \( p < 0.001 \) compared to male by unpaired t-test.
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Results and Discussion

The characteristics of the 49 subjects are shown in Table 1, and the polyphenol intake is summarized in Table 2. The subjects consumed 567±236 mg/d of polyphenols on average. The polyphenol intake from beverages was 354±223 mg/d, accounting for 62% of the total polyphenol intake. The largest source of polyphenol intake was green tea at 26.8% (152±72 mg/d) followed by coffee at 19.3% (109±35 mg/d), then by black tea, Chinese tea, onion, chocolate, tofu, natto, miso, and soy sauce at 6.3%, 5.1%, 4.4%, 3.7%, 3.1%, 3.0%, 2.1%, and 1.9%, respectively. Soybean products together accounted for 10.1%, as the third largest contributor after green tea and coffee. Our previous studies identified that middle-aged to elderly Japanese populations consumed 841–1,492 mg/d of polyphenols on average, and that beverages were a large source of total polyphenol (approx. 80%) (3, 5, 7, 8).

According to a study using the same FFQ for the estimation of polyphenol intake (5), the mean polyphenol intake from green tea and from coffee in older adults was 397 mg and 645 mg, respectively, which was 2.6 times and 5.9 times that obtained by this young adults. Although our present subjects consumed less total polyphenol due to their lower intake of green tea and coffee compared to our earlier studies’ older Japanese subjects, the major contributors to total polyphenol intake were also beverages. Moreover, the top 10 food and beverage items of the polyphenol intake in our present subjects were almost the same as those in our earlier studies’ middle-aged to elderly Japanese populations (3, 5), indicating that a very limited variety of items could contribute to the dietary polyphenol intake in Japanese. Regarding gender, there were no differences in the polyphenol intake between male and female except for polyphenol intake from confectioneries.

Table 3 shows the polyphenol intake in February, May, August and November. The polyphenol intake values were not adjusted for energy because the dietary energy intakes in the four seasons did not differ significantly from each other (1,609 kcal in February, 1,568 kcal in May, 1,531 kcal in August, 1,515 kcal in November). No significant differences were found in the total polyphenol intake or polyphenol intake from beverages among the four seasons. However, we observed significant seasonal differences in the polyphenol intake from food; the polyphenol intake from food in February (255±111 mg/d) was significantly higher than those in May (215±91 mg/d), August (187±82 mg/d) and November (196±88 mg/d) (p<0.0001). Regarding food groups, there were significant seasonal differences in the polyphenol intakes from vegetables, fruits, and confectionery (p=0.001, 0.005, and 0.002, respectively). Our earlier studies revealed that the polyphenol intake from beverages (4) and the polyphenol intake from vegetables and fruits (6) were high in winter and low in summer. We therefore expected that the total polyphenol intake of the present subjects would be higher in winter, but the present survey showed no significant seasonal differences in their total polyphenol intake.

Our present subjects in their twenties consumed less coffee and/or green tea (which were the major contributors to the total polyphenol intake) compared to our earlier studies’ older Japanese subjects. In a beverage consumption survey among Japanese individuals (n>10,000, aged 1–99 y) (4), we found that the polyphenol intake increased according to the subjects’ age depending on the increase of coffee and/or green tea consumption, and that the proportions of total beverage consumption varied with the seasons; the subjects consumed more beverages rich in polyphenols in the winter.
The amount of coffee and/or green tea was responsible for the seasonal changes observed in the previous beverage survey.

Therefore, the lower consumption of coffee and green tea throughout the year in the present subjects might have contributed to the unexpected finding that there were no significant seasonal differences in total polyphenol intake or polyphenol intake from beverages. On the other hand, the students’ polyphenol intake from food showed a seasonal difference. The amounts and the source of polyphenol intake from food in these subjects were almost the same as those in our previous studies’ older adult subjects. To identify the influence of age and season on polyphenol intake, a further study covering all generations is needed.

To our knowledge, this study is the first to evaluate the total polyphenol intake in young adults and also to investigate its seasonal changes. The researchers in most of the previous studies investigated middle-aged to elderly subjects, due to their interest in the associations between polyphenol intake and the risk of chronic diseases. Younger populations’ polyphenol intake has scarcely been investigated. A small amount of information about flavonoid intake among young adults (19 to ~30 y) is available from the studies that were based on national health and nutrition surveys in Korea and the U.S. (10). We have been unable to find any study investigating the total polyphenol intake of young adults.

Regarding seasonal variation, only one study has focused on the seasonal changes of antioxidants intake; Pysz et al. reported that children and adolescents living in orphanages in Krakow, Poland generally consumed higher amounts of polyphenols during the winter and autumn than in other seasons (11). However, that study did not assess the individual beverage intake in the children and adolescents.

Our study has some limitations. Its design was cross-sectional and not population-based. The number of males (n=17) and females (n=32) was not balanced, but there were almost no differences in the polyphenol intake between the sexes. In addition, our study was of Japanese university students, whose polyphenol intake might be lower than that of older adults. The present results therefore may not be applicable to other populations. Further studies are needed to clarify seasonal variations in dietary polyphenol intake.

In conclusion, the total polyphenol intake of Japanese university students was estimated to be 567 ± 236 mg/d on average, which was lower than the intake of older Japanese adults. A significant seasonal difference was observed in the polyphenol intake from food, and the highest intake was in February (winter). These findings should assist in future estimations of dietary polyphenol intakes that consider differences according to age and season.

Acknowledgments

This work was supported by a JSPS KAKENHI grant, no. 15K16229. We are grateful to the volunteers for participating in the study. The authors declare no conflict of interest associated with this manuscript.

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