Iodine intake by adult residents of a farming area in Iwate Prefecture, Japan, and the accuracy of estimated iodine intake calculated using the Standard Tables of Food Composition in Japan

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Abstract

Objectives Iodine intake by adults in farming districts in Northeastern Japan was evaluated by two methods: (1) government-approved food composition tables based calculation and (2) instrumental measurement. The correlation between these two values and a regression model for the calibration of calculated values was presented.

Methods Iodine intake was calculated, using the values in the Japan Standard Tables of Food Composition (FCT), through the analysis of duplicate samples of complete 24-h food consumption for 90 adult subjects. In cases where the value for iodine content was not available in the FCT, it was assumed to be zero for that food item (calculated values). Iodine content was also measured by ICP-MS (measured values).

Results Calculated and measured values rendered geometric means (GM) of 336 and 279 μg/day, respectively. There was no statistically significant (p > 0.05) difference between calculated and measured values. The correlation coefficient was 0.646 (p < 0.05).

Discussion With this high correlation coefficient, a simple regression line can be applied to estimate measured value from calculated value. A survey of the literature suggests that the values in this study were similar to values that have been reported to date for Japan, and higher than those for other countries in Asia.

Conclusions Iodine intake of Japanese adults was 336 μg/day (GM, calculated) and 279 μg/day (GM, measured). Both values correlated so well, with a correlation coefficient of 0.646, that a regression model (Y = 130.8 + 1.9479X, where X and Y are measured and calculated values, respectively) could be used to calibrate calculated values.

Keywords Adult · Dietary intake · Food composition tables · Iodine · Japanese

Introduction

Iodine (I) is an essential nutrient in the human diet [1]. However, excess iodine ingestion, as well as insufficient intake, may induce health disorders [2]. Hence, the estimated average requirement (EAR) or recommended dietary allowance (RDA) and tolerable upper intake level (UL) for iodine have been established and are publicized in the Dietary Reference Intakes issued by the Ministry of Health, Labour and Welfare in Japan [3].

To keep iodine intake within lower and upper limits, an accurate method of estimating iodine quantities in food is needed. The two methods of evaluating intake are (1) estimation by calculation and (2) instrumental measurement. The calculation method made use of the Japan Standard Tables of Food Composition (FCT) [4–6]. However, the FCT remains incomplete for iodine content, and concern has arisen over the reliability of calculated levels [7]. Instrumental measurement of iodine intake would be accurate, but expensive and time-consuming, and,
therefore, impractical for use on a daily basis. Thus, information on the reliability of calculated values and a method for calibration are needed [8].

In a previous study [9], daily iodine intake for children was assessed by these two methods and the results were compared. It was found that the values attained by the two methods correlated closely, and the calibrated values derived from calculated values were sufficiently accurate to apply in daily situations. A regression model for calibrating the calculated daily iodine intake of children was published [9].

In this study, iodine intake from typical meals eaten by adult residents in rural farming districts in Northeastern Japan was assessed using both the methods. The accuracy of the calculated results for adults was evaluated and a regression model for the calibration of the calculated values was presented. Finally, comparisons between the results for children and adults were discussed.

**Materials and methods**

**Ethical issues**

The study protocol was approved by the Ethics Committee of Iwate Prefectural University Morioka Junior College, Japan (Approval Number 40).

**Study participants and duplicate food sample collection**

The study was conducted in four farming areas of Iwate Prefecture in Northeastern Japan over a 2-year period, from December in 2011, February and March in 2012 to April in 2013. Adult subjects recruited through the agricultural cooperative union were farmers and their wives. All participants underwent assessment by a doctor and medical statistics, i.e., height, body weight and percentage of body fat, blood pressure, liver function, total cholesterol, triglyceride and hemoglobin, etc., were recorded, but thyroid gland function was not tested. All participants were shown to be in good health. Both calculated and measured values were available for these 90 volunteer subjects (23 men and 67 women, average age 60.6) and further statistical analyses were conducted with these same subjects. There were 11 married couples among the 90 subjects.

Each participant submitted his/her 24-h duplicate food samples [10]. Participants were instructed to prepare their regular meals (i.e., no particular dishes were recommended) for one whole day, including any snacks, tea, and drinks. Researchers were provided with complete duplicate meals together with information on the ingredients of each dish. Each food item in the sample was separated manually and weighed under the supervision of experienced nationally registered dietitians. Since seasonings or spices are water-soluble and/or too small to be separated or weighed, and liquid ingredients, oil and soup stock, for example, cannot be separated, dietitians interviewed participants about what was used and weights were estimated. After separating and weighing, the total 24-h food sample for each subject was homogenized in a blender.

**Food composition table-based calculation of dietary iodine intake (calculated values)**

The FCT was revised in December, 2015 [5]. However, the 2010 edition [4] was used in this study, as it was the most recent edition available at the time of food collection. Food items collected in the duplicated food samples were identified by referring to the classifications in the FCT. Daily iodine intake was calculated from food weights and the corresponding iodine content listed in the FCT. At the time of this study, the 2010 FCT was incomplete for certain nutrients, including the iodine content, for particular food items. In cases where the value for iodine content was not available in the FCT, it was assumed to be zero for that food item [4].

**Instrumental analysis for iodine (measured values)**

Since the process for instrumental analysis has already been described in detail in a previous study on children [9], a short description will be given here. A portion (2.5 g) of the homogenate was wet-digested under the alkaline conditions. After centrifugation to remove solid materials, the sample was subjected to analysis for iodine by inductively coupled plasma mass spectrometry (ICP-MS).

**Estimation of insufficient or excess intake of iodine**

According to the 2010 edition of the Dietary Reference Intakes published by the Ministry of Health, Labour and Welfare in Japan, the EAR for iodine was 95 μg/day, the RDA was 130 μg/day, and the UL for iodine at the time of this study was 2200 μg/day [3]. In the 2015 edition, the former two values remain as in the 2010 edition, and the latter has been revised to 3000 μg/day [11]. In this study, 2200 μg/day was used, because it was the value at the time of study. These guidelines were used [3] to distinguish among insufficient, adequate, and excess intake of iodine.

**Statistical analysis**

The present analyses indicated that the daily intake levels of iodine were distributed approximately log-normally (Fig. 1a, b). Thus, statistical analyses were conducted as
observed and after logarithmic conversion. That is, geometric means (GM), geometric standard deviations (GSD), and median (MED) were taken as representative parameters, as well as arithmetic mean (AM) and arithmetic standard deviation (ASD). Foods were grouped to conform to FCT categorizations [4]. Intake of each food group (in grams), iodine intake derived from each food group, and the percentage of iodine intake from each food group relative to total iodine intake were calculated.

The correlation between the calculated and measured values was determined by Pearson’s correlation. In addition, the simple regression analysis was done on calculated and measured values. Pearson’s correlation and simple regression analysis were conducted both for observed and after logarithmic conversion. The statistical difference between averages was determined by two-sided paired t test. A difference of $p < 0.05$ was considered significant. In all the analyses, Excel version 2013 (Microsoft Corporation) was used.

### Results

The physical constitution of the subjects is summarized in Table 1. Table 2 shows a brief summary of nutrients taken by the subjects. There is no significant variance between these values and the results obtained from the National Health and Nutrition Survey in Japan 2010 [12].

Statistics for calculated and measured values are summarized in Table 3. The MED (GM) of daily iodine intake for calculated values was 170 (336) $\mu$g/day and for measured values 213 (279) $\mu$g/day. The difference between the two GMs was not statistically significant ($p > 0.05$). The GM ratio was 279/336 = 0.830. The ranges were wide, 24,370 (13–24383, minimum and maximum, respectively) $\mu$g/day for calculated value and 15,304 (26–15330) $\mu$g/day for measured value.

Distribution patterns for both calculated and measured values were approximately log-normal, with measured values closer to log-normal than the calculated values, and the latter with a longer tailing towards higher values (Fig. 1a, b). The 75-percentile value was 2437 $\mu$g/day for calculated values, and 662 $\mu$g/day for measured values. Due to the wide range, there was no significant ($p > 0.05$) difference in GM between men and women.

Thirty-two out of ninety subjects (35.6 %) had calculated values that were less than EAR (Fig. 1a), and 18 subjects (20.0 %) had measured values that were below EAR (Fig. 1b). Twenty-three out of ninety subjects (25.6 %) had calculated values that were over UL (Fig. 1a) and six subjects (6.67 %) had measured values that were over UL (Fig. 1b). For the 23 subjects whose calculated values were over UL, most iodine was derived from Group 9 (Algae), 98.0 % on average.

Table 4 shows the intake of each food group, iodine intake derived from each food group according to the FCT [4], and the percentage of iodine intake from each food group relative to total iodine intake. The AM of algae intake was as little as 10 g with wide deviations (ASD was 14 g). Because of the high iodine content in algae, average iodine intake from algae made up about half of total values, with wide deviations. The second source of iodine was milk and the third was egg, also with large deviations.
Analysis for relation revealed that the pairs of calculated and measured values correlated significantly ($p < 0.05$) with a correlation coefficient of 0.646. The regression line was $Y = 1302.5 - 1.9479X$, where $X$ and $Y$ were measured and calculated values of $\text{lg}$/day, respectively. When values were logarithmically converted, logarithms of measured and calculated values also correlated significantly, with a correlation coefficient of 0.691 ($p < 0.05$). The regression line was $Y = -0.4117 - 1.2016X$, where $X$ and $Y$ were logarithms of measured and calculated values.

**Discussion**

Physical characteristics, as shown in Table 1, and nutrients intake in Table 2, are comparable with the averages in the National Health and Nutrition Survey [12] for Japan. Hence, the study subjects and their meals were typical of national norms.

Japan is surrounded by the sea and the Japanese population consumes seafood in large quantities, especially

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**Table 1** Physical constitution and blood pressure of the subjects

| Sex | N | Age (cm) | Weight (kg) | Body fat (%) | BMI (kg/m²) | Blood pressure (mmHg) |
|-----|---|----------|-------------|--------------|-------------|-----------------------|
|     |   |          |             |              |             | Systolic | Diastolic |
| Men | 23 | 60.3     | 166.5       | 66.8         | 23.9        | 24.1      | 124.7 | 75.2 |
|     |    | AM       | ASD         |              |             |           |          |        |
| Women | 67 | 60.7     | 153.9       | 56.0         | 32.7        | 23.7      | 120.5 | 74.6 |
|     |    | AM       | ASD         |              |             |           |          |        |
| Total | 90 | 60.6     | 157.1       | 58.8         | 30.4        | 23.8      | 121.6 | 74.7 |
|     |    | AM       | ASD         |              |             |           |          |        |

AM arithmetic mean, ASD arithmetic standard deviation, $N$ number of subjects

**Table 2** Intakes of energy and nutrients by the calculation method

|          | Men | Women | Total |
|----------|-----|-------|-------|
|          | AM  | ASD   | AM    | ASD   | AM    | ASD   |
| Energy (kcal) | 2395 | 1829 | 1974 | 473.6 |
| Protein (g)   | 77.5 | 66.4 | 69.2 | 18.7 |
| Lipid (g)     | 52.9 | 49.1 | 50.1 | 15.8 |
| Carbohydrate (g) | 348.8 | 275.3 | 294.1 | 79.0 |
| Salt (g)      | 10.1 | 8.9  | 9.2  | 2.6  |
| Calcium (mg)  | 637  | 623  | 627  | 257  |
| Phosphorus (mg) | 1192 | 1034 | 1075 | 315  |
| Iron (mg)     | 10.0 | 8.7  | 9.0  | 3.5  |
| Iodine ($\mu$g) | 2021 | 1034 | 1075 | 315  |
| Vitamin A (RE) ($\mu$g) | 555 | 517 | 527 | 231.0 |
| Vitamin D ($\mu$g) | 8.9 | 7.9 | 8.2 | 7.3 |
| Thiamin (mg)  | 0.93 | 0.78 | 0.82 | 0.28 |
| Ascorbic acid (mg) | 19 | 18 | 18 | 6.4 |
| Dietary fibers (g) | 19 | 18 | 18 | 6.4 |

AM arithmetic mean, ASD arithmetic standard deviation, RE retinol activity equivalent

Analysis for relation revealed that the pairs of calculated and measured values correlated significantly ($p < 0.05$) with a correlation coefficient of 0.646. The regression line was $Y = 1302.5 + 1.9479X$, where $X$ and $Y$ were measured and calculated values of $\mu$g/day, respectively. When values were logarithmically converted, logarithms of measured and calculated values also correlated significantly, with a correlation coefficient of 0.691 ($p < 0.05$). The regression line was $Y = -0.4117 + 1.2016X$, where $X$ and $Y$ were logarithms of measured and calculated values.

**Table 3** Iodine intake values by calculation and measurement

| Sex | N | AM | ASD | MED | 75 %-tile | MIN | MAX | GM | GSD |
|-----|---|----|-----|-----|----------|-----|-----|----|-----|
|     |   |    |     |     |          |     |     |    |     |
| Calculated value | | | | | | | | | |
| Men | 23 | 2621 | 5735 | 139 | 867 | 13 | 24383 | 222 | 8 |
| Women | 67 | 2741 | 5214 | 182 | 3065 | 13 | 23891 | 388 | 9 |
| Sum | 90 | 2710 | 5324 | 170 | 2437 | 13 | 24383 | 336 | 9 |
| Measured value | | | | | | | | | |
| Men | 23 | 1087 | 3121 | 202 | 350 | 39 | 15330 | 248 | 4 |
| Women | 67 | 598 | 882 | 232 | 673 | 26 | 4692 | 290 | 3 |
| Sum | 90 | 723 | 1774 | 213 | 662 | 26 | 15330 | 279 | 3 |

AM arithmetic mean, ASD arithmetic standard deviation, $N$ number of subjects

MAX maximum, MED median, MIN minimum, GM geometric mean, GSD geometric standard deviation
| Food group                  | Intake of each food group (g) | Iodine intake (µg) | Percentage (%) |
|----------------------------|-------------------------------|-------------------|----------------|
|                            | Men AM | ASD | Women AM | ASD | Total AM | ASD | Men AM | ASD | Women AM | ASD | Total AM | ASD | Men AM | ASD | Women AM | ASD | Total AM | ASD |
| Cereals                    | 607    | 181 | 413     | 104 | 462     | 154 | 0      | 0   | 0      | 0   | 0      | 0   | 0.3    | 0.8 | 0.3     | 0.6 | 0.3     | 0.7 |
| Potatoes and starches      | 58     | 80  | 39      | 37  | 44      | 52  | 0      | 0   | 0      | 0   | 0      | 0   | 0.1    | 0.2 | 0.0     | 0.1 | 0.0     | 0.2 |
| Sugars and sweeteners      | 7      | 11  | 6       | 11  | 6       | 11  | 0      | 0   | 0      | 0   | 1      | 1   | 0.0    | 0.0 | 0.0     | 0.1 | 0.0     | 0.1 |
| Pulses                     | 69     | 61  | 96      | 98  | 89      | 90  | 2      | 3   | 2      | 3   | 2      | 3   | 3.1    | 5.5 | 2.7     | 7.4 | 2.8     | 7.0 |
| Nuts and seeds             | 2      | 4   | 3       | 9   | 3       | 8   | 0      | 0   | 0      | 0   | 0      | 0   | 0.0    | 0.0 | 0.0     | 0.1 | 0.0     | 0.0 |
| Vegetables                 | 306    | 137 | 276     | 94  | 283     | 107 | 2      | 2   | 2      | 2   | 2      | 2   | 3.7    | 8.7 | 2.3     | 5.4 | 2.6     | 6.4 |
| Fruits                     | 101    | 110 | 179     | 125 | 159     | 125 | 0      | 0   | 0      | 0   | 0      | 0   | 0.0    | 0.1 | 0.1     | 0.2 | 0.0     | 0.2 |
| Mushrooms                  | 12     | 13  | 13      | 13  | 12      | 13  | 0      | 0   | 0      | 0   | 0      | 0   | 0.0    | 0.0 | 0.0     | 0.0 | 0.0     | 0.0 |
| Algae                      | 10     | 14  | 11      | 14  | 10      | 14  | 251    | 23  | 266    | 137 | 262    | 143 | 40.3   | 41.5 | 56.1    | 42.9 | 52.0    | 42.9 |
| Fishes and shellfishes     | 69     | 53  | 58      | 42  | 61      | 45  | 9      | 13  | 13      | 37  | 12      | 32  | 8.9    | 11.2 | 6.6     | 15.2 | 7.2     | 14.2 |
| Meats                      | 66     | 54  | 40      | 35  | 47      | 42  | 0      | 0   | 0      | 0   | 0      | 0   | 0.0    | 0.0 | 0.0     | 0.0 | 0.0     | 0.0 |
| Eggs                       | 38     | 36  | 34      | 45  | 35      | 43  | 44     | 124 | 21      | 73  | 27      | 89  | 9.7    | 13.1 | 6.9     | 14.6 | 7.6     | 14.2 |
| Milks                      | 130    | 145 | 144     | 144 | 141     | 143 | 19     | 23  | 20      | 22  | 20      | 22  | 17.0   | 23.2 | 15.5    | 26.6 | 15.9    | 25.6 |
| Fats and oils              | 7      | 4   | 7       | 4   | 7       | 4   | 0      | 0   | 0      | 0   | 0      | 0   | 0.0    | 0.1 | 0.0     | 0.1 | 0.0     | 0.1 |
| Confectioneries            | 25     | 32  | 47      | 67  | 42      | 61  | 0      | 1   | 3      | 8   | 2      | 7   | 0.4    | 1.1 | 1.8     | 7.0 | 1.4     | 6.1 |
| Beverages                  | 621    | 446 | 462     | 372 | 503     | 397 | 4      | 5   | 1      | 1   | 2      | 3   | 6.0    | 9.6 | 0.4     | 0.8 | 1.8     | 5.5 |
| Seasonings and spices      | 51     | 13  | 48      | 25  | 49      | 23  | 21     | 33  | 17      | 30  | 18      | 31  | 10.5   | 21.4 | 7.3     | 18.6 | 8.1     | 19.3 |
| Prepared foods             | 16     | 38  | 16      | 33  | 16      | 34  | 0      | 1   | 0      | 1   | 0      | 1   | 0.0    | 0.1 | 0.0     | 0.2 | 0.0     | 0.2 |
| Others                     | 558    | 403 | 506     | 320 | 519     | 342 | 0      | 0   | 0      | 0   | 0      | 0   | 0.0    | 0.0 | 0.0     | 0.0 | 0.0     | 0.0 |
| Total                      | 2752   | 755 | 2398    | 472 | 2488    | 578 | 2621   | 5735| 2741    | 5214| 2710    | 5324| 100    | 100 | 100     | 100 | 100     | 100 |

Iodine intake values are by calculation.

Food group was compliant to the Standard Tables of Food Composition in Japan.

*AM* arithmetic mean, *ASD* arithmetic standard deviation.
As seaweeds have high iodine content [4], Japanese people can be expected to take in more iodine than people in other countries [14–18].

Tsukada et al. [7] reported that Japanese students’ intake of iodine from FCT-based data was 339 µg/day as MED, and Imaeda et al. [15] calculated iodine intake of 312 and 413 µg/day as MED for men and women, based on the FCT values. Fuse et al. reported higher values of 880.4 µg/day as GM (931.1 µg/day MED) for women [16], and 605.5 and 539.7 µg/day as MED for men and women, respectively [17]. These reported values for Japan were greater than the values in this study. Considering the wide range in other studies, the values determined in this study appear to be consistent with the levels published in other reports [7, 14–17] on Japanese iodine intake.

Iyengar et al. reported on the dietary intake of seven elements of importance in radiological protection by Asian populations, including iodine as one of the seven elements [18]. MED of daily iodine intake was 326.8 µg for China, 85.0 for India, 246.0 for Japan, 86.98 for the Republic of Korea, 43.47 for Pakistan, 30.0 for the Philippines, and 1449 for Vietnam. The high levels in China and Vietnam may be due to the use of iodized salt [18, 19]. The median intake for other Asian countries was 90 µg/day which was lower than the values in this study and in other reports on Japan [7, 15–17, 20]. The lower values in Asia and the fact that iodine is not added to Japanese table salt suggest that the Japanese population generally takes in sufficient levels of iodine from daily foods.

According to the 2014 National Health and Nutrition Survey [12], Japanese consumed 75.6 g/day of fish and shellfish, and 10.5 g/day of algae [12, 13]. These foods contain much iodine [4], thus, the high Japanese intake of iodine is derived from seafood, particularly algae. Algae and algae extracts are often used in Japanese cooking as taste enhancers. Some potato chips in Japan, for example, contain as much as 260 µg/100 g of iodine because of the flavor enhancers used [4]. In Japan, miso (bean paste) soup is consumed frequently and its taste is usually enhanced with soup stocks that include extracts from seafood and seaweed. In general, konbu (kelp, especially high in iodine), katsuo-bushi (shaved dried bonito), or niboshi (small dried sardines) are boiled in hot water to make a soup base or stock; these initial stock ingredients are then removed before miso and other ingredients are added.

Since these taste enhancing ingredients are removed during cooking and were not present in the duplicate sample, there was concern that they might have been overlooked and the iodine intake underestimated [14]. However, in this study, potential undervaluing of the iodine content did not take place because of the reasons below. Miso soup is certainly consumed frequently in the study area; however, konbu and katsuo-bushi are rarely used for soup stock in ordinary family cooking here. Instead, niboshi is frequently used, and differently from other parts of Japan, the niboshi is not removed but ingested. The duplicate samples contained niboshi and were counted as one of the miso soup ingredients.

These days in the study area, granule, or extract mix type ready-made soup stocks are used for not only miso soup but also many kinds of dishes. These soup stocks contain some iodine [14], but the granules are water soluble and the extract mix is liquid, so the granules cannot be separated and weighed. However, in this study, when the duplicate samples were collected, dietitians interviewed participants about what ingredients were used, including ingredients for soup stocks, and weights were estimated. For these reasons, iodine in soup stocks and algae extracts were counted and there was no underestimation of iodine intake.

Some of the sample meals in this study indicated both insufficient and excess iodine. This does not necessarily mean a persistent shortage or excess that could induce a disorder. The range of iodine intake was wide and the research period was only one day. Algae, with its high iodine content, are frequently consumed in Japan. Dried konbu has an iodine content of 240 mg/100 g [4], so that a 1 g intake immediately raises the iodine level from insufficient to excess. For these reasons, it is likely that over an

![Fig. 2 Correlation between measured values and calculated values after the logarithmic conversion of daily iodine intake. Each dot represents one case, and the line in the middle is a calculated regression line of \( Y = -0.4117 + 1.2016X \) \( (r = 0.691, p < 0.05) \), where \( X \) and \( Y \) are log measured and calculated values (in µg/day), respectively. The dotted curves on both the sides of the regression line show the 95% limit of the means.](image-url)
extended period of time, Japanese adults probably take in adequate iodine [20].

As stated in the introduction, for food items where a value for iodine content was not available in the FCT, the value was assumed to be zero in this study. At the time of study, the 2010 FCT listed 1878 food items, of which iodine content data were available for only 518 food items (27.6 %). Comprehensive information in the FCT on iodine content by food group varied from a high of 51.4 % for Group 5 (nuts and seeds), to a low of 16.0 % for both Group 11 (fish and shellfish) and Group 12 (meats). Even for Group 9 (algae), the expected leading source of dietary iodine in Japan [14], the iodine content value was available for only 18 items out of a total of 47 types of algae (38.3 %) [4, 13, 14].

Thus, calculated values were expected to be lower than the measured values. In the previous study with children aged 3–6 years [9], the calculated values (101.8 in GM, 90.9 for MED) were, in fact, lower than the measured values (117.6 in GM, 96.3 for MED). Therefore, the ratio for children was 1.155 [9], i.e., more than 1.00. This higher ratio may be attributable to the unknown iodine content in certain foods. However, in this study, the differences between the GM of calculated and measured values were statistically insignificant (p > 0.05), and the calculated values tended to be larger than the measured values and the ratio of GMs was 0.830, i.e., less than 1.00. This low ratio cannot be interpreted as a consequence of iodine quantities missing from food items listed in the FCT. The distribution of values from the calculated method had a longer tailing toward higher values than that from the measured values (Fig. 1a, b) and the 75-percentile value for calculated value was larger than that for measured (Table 3). These high values in the distribution of calculated values were represented in the low ratio. Nonetheless, since the study on children used the same methods as the study on adults, the explanation for the different results between the two studies is unclear.

The second purpose of this study was to validate the correlation between calculated and measured values to calibrate calculated values. The two values in this study correlated well (Fig. 2), with a correlation coefficient of 0.646 (p < 0.05). The regression line was \( Y = 130.5 + 1.9479X \), where \( X \) and \( Y \) were observed, measured and calculated values, respectively. With such high correlation, this formula can be applied to estimate the counterpart values, i.e., from \( X \) to \( Y \) and vice versa. For log values, with a correlation coefficient of 0.691 (p < 0.05), the regression line was \( Y = -0.4117 + 1.2016X \), where \( X \) and \( Y \) were log measured and calculated values, respectively.

The regression line in this study differed from that in the previous study on children [9]. Namely, the slope and the intercept both differed significantly (p < 0.05) between this study and the child study (\( Y = 1.02 + 0.48X, r = 0.422, p < 0.01, X \) and \( Y \) were log measured and calculated values, respectively, both in µg/day). A regression formula that could be applied to a wide range in age and iodine intake is desirable, thus the data of this study on adults and that of the previous study on children were merged to validate the regression formula for the merged data.

When the data on the two studies were combined, the regression line was \( Y = 408.3 + 2.0664X \), where \( X \) and \( Y \) were measured and calculated values, respectively, with a correlation coefficient 0.667 (p < 0.05). For log values, with a correlation coefficient 0.657 (p < 0.05), the regression line was \( Y = 0.0343 + 0.9793X \), where \( X \) and \( Y \) were log measured and calculated values, respectively (Fig. 3). These high correlation coefficient values indicate that a single regression line could be applied to a wide age range. Further research nationwide with a larger number of study participants of all ages is necessary to obtain a common regression line that can be generalized across all age groups.

There were several limitations in this study. First, the participants studied were exclusively from the one prefecture of Iwate, although Japan has a total of 47
prefectures. It is true that food intake varies according to locality [12, 20]. In some fishing villages in the northern part of Japan, seaweeds are cultivated, and if a study region were to include these villages, the average iodine intake may be higher than the present results [20].

Second, the study period, the age range, and the number of subjects were limited. The study period was for one day only, so that day-by-day and inter-seasonal variations could not be considered. A comprehensive multi-generational survey is required to generalize the regression equivalent formula and to develop a more reliable means of approximating calculated values to true values.

In conclusion, within the limitations cited above, daily intake of iodine for adults in Iwate Prefecture was 336 μg/day as GM for calculated value and 279 μg/day as GM for measured value. Both values correlated so well, with a correlation coefficient of 0.646, that our regression model (\(Y = 130.8 + 1.9479X\), \(X\) and \(Y\) as measured and calculated values, respectively) could be used to calibrate calculated values.

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Compliance with the ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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