Original Article

Association of *trans* fatty acid intake with metabolic risk factors among free-living young Japanese women

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日本年輕女性反式脂肪酸的攝取與代謝危險因子之相關

目的：橫斷性研究日本年輕女性的總反式脂肪酸、氫化或天然反式脂肪酸的攝取與選定的代謝危險因子之關係。方法：研究對象為 1136 名日本營養系女學生，年齡 18-22 歲。飲食攝取評估使用效度已確認的，自我評估飲食歷史問卷。反式脂肪酸的攝取與代謝危險因子之相關，利用多元線性迴歸分析，控制潛在的共變量。飲食共變量包括總熱量攝取、總脂肪和飽和脂肪酸（模式 1），單元不飽和脂肪酸替代飽和脂肪酸（模式 2），和多元不飽和脂肪酸替代飽和脂肪酸（模式 3）。結果：平均（標準差）總反式脂肪酸攝取佔總熱量的 0.90%（0.30%）。氫化反式脂肪酸攝取佔總反式脂肪酸的 77%。總反式脂肪酸與腰圍、三酸甘油酯和糖化血紅素幾乎都有顯著的正相關，僅有校正單元不飽和脂肪酸後的三酸甘油酯例外。總反式脂肪酸攝取與身體質量指數、膽固醇或血糖沒有相關性。氫化反式脂肪酸攝取只與腰圍和糖化血紅素有顯著正相關。天然反式脂肪酸未發現有相關。結論：在相對攝取量較低的日本年輕女性中，氫化反式脂肪酸攝取與一些代謝危險因子有顯著正相關。

關鍵詞：反式脂肪酸攝取、代謝危險因子、年輕日本女性、橫斷性研究、亞洲人口

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Original Article

Estimation of *Trans* Fatty Acid Intake in Japanese Adults Using 16-Day Diet Records Based on a Food Composition Database Developed for the Japanese Population

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ABSTRACT

Background: The Standard Tables of Food Composition in Japan do not include information on *trans* fatty acids. Previous studies estimating *trans* fatty acid intake among Japanese have limitations regarding the databases utilized and diet assessment methodologies. We developed a comprehensive database of *trans* fatty acid food composition, and used this database to estimate intake among a Japanese population.

Methods: The database was developed using analytic values from the literature and nutrient analysis software encompassing foods in the US, as well as values estimated from recipes or nutrient compositions. We collected 16-day diet records from 225 adults aged 30 to 69 years living in 4 areas of Japan. *Trans* fatty acid intake was estimated based on the database and the 16-day diet records.

Results: Mean total fat and *trans* fatty acid intake was 56.9 g/day (27.7% total energy) and 1.7 g/day (0.8% total energy), respectively, for women and 66.8 g/day (25.5% total energy) and 1.7 g/day (0.7% total energy) for men. *Trans* fatty acid intake accounted for greater than 1% of total energy intake, which is the maximum recommended according to the World Health Organization, in 24.4% of women and 5.7% of men, and was particularly high among women living in urban areas and those aged 30–49 years. The largest contributors to *trans* fatty acid intake were confectionaries in women and fats and oils in men.

Conclusions: Although mean *trans* fatty acid intake was below the maximum recommended intake of the World Health Organization, intake among subgroups was of concern. Further public health efforts to reduce *trans* fatty acid intake should be encouraged.

Key words: food composition database; *trans* fatty acids; Japanese population

INTRODUCTION

Industrially produced *trans* fatty acids, formed during the partial hydrogenation of commercial liquid vegetable oils to semi-solid fats, are found in margarine, shortening, and frying fats. Intake of these *trans* fatty acids is associated with metabolic and inflammatory risk factors and diseases, including coronary heart disease.[1–3] Although small amounts are also found in ruminants as a result of biohydrogenation of polyunsaturated fatty acids, the few studies investigating such naturally derived *trans* fatty acid intake have found no association with some risk factors or with coronary heart disease,[2–5] although the results were inconsistent.[4] The World Health Organization (WHO) recommends that *trans* fatty acid

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intake be limited to less than 1% of total energy intake.[6] Several Western countries have taken action to regulate consumption[7]: Denmark became the first country to ban fats and oils with greater than 2% industrially produced *trans* fatty acids in 2003[8]; the Netherlands has set an upper intake level of *trans* fatty acids of 1% of total energy intake[9]; and the Unites States (US) has mandated *trans* fatty acid listing on food labels[10] and recommended that intake be as low as possible.[11]

Any investigation of the effects of *trans* fatty acid in specific populations should begin with the estimation of *trans* fatty acid intake in that population. However, few data are available on individual mean intakes estimated using *trans* fatty acid food composition tables covering foods high in *trans* fatty acids[1,12,13] in Asian countries, including Japan. Several estimates for Japanese populations have been reported,[14–19] but their usefulness is limited by problems with databases,[14–18] dietary assessment methodologies,[15–18] or sample sizes.[15,19] Thus, our aim in this study was to develop a comprehensive *trans* fatty acid database that encompasses broader categories of foods, and then to estimate *trans* fatty acid intake among a Japanese population by using 16-day diet records (DR).

METHODS

Development of a *trans* fatty acid database

Number of food items and data sources

We developed a *trans* fatty acid database for 1995 foods: 1976 foods appearing in the Standard Tables of Food Composition in Japan (STFCJ)[20] and 19 foods added in the present study. Among these 1995 foods, 1469 were found to contain no *trans* fatty acids (because they contained no or only a trace amount of fat[20]) and no industrially produced hydrogenated oils or ruminants.[12,13,21–33]

The primary data source for *trans* fatty acid values for the remaining 526 foods was direct chemical analysis.[17–19,21–33] For this, we searched the Pubmed, CiNii, and Medical Online Library databases for the English and Japanese literature reporting analyses conducted in Japan of the *trans* fatty acid content of foods. For the present study, we limited data to reports appearing after the year 1992 (ie, data reported during the decade preceding collection of the present diet records) in order to minimize the possibility of changes in the nutrient composition of food products. Using these articles and their reference lists, we selected articles that assessed *trans* fatty acid content in foods by gas chromatography only.[34] One article that did not indicate the number of samples analyzed[32] was included, but was excluded from calculation when identical foods were analyzed in multiple articles, since the calculation of a mean value required the number of samples to be known. Further, we included data on analytic *trans* fatty acid values of 3 foods provided in the STFCJ[20] (soft margarine, fat spread, and shortening) and unpublished data on 2 foods referenced in the STFCJ (Maruyama T, personal communication).

In addition, we reviewed the literature of other countries reporting foods with a high *trans* fatty acid content[12,13,35–39] and selected those foods that were not included in the STFCJ.[20] This process identified 19 foods determined to be important sources of *trans* fatty acids for addition to the database, including fast foods ($n = 11$), baked goods ($n = 5$), and confectionaries ($n = 3$). Fast foods were added because the STFCJ[20] included only 1 fast food item (french fries) and omitted others (eg, hamburgers and fried chicken) produced by the major fast food chains.[40] Regarding baked goods and confections, although 15 baked goods and 150 confectionaries were included in the STFCJ, we did not include other top-selling baked goods (eg, pastry with icing and muffins) and confectionaries (eg, almond chocolate and chocolate cake)[41] with high levels of *trans* fatty acids.

When analytic data were unavailable, as a secondary data source we used data from the ESHA Food Processor SQL, which covers more than 35 000 foods, including food products and fast foods sold in the US (ESHA Research, Salem, Oregon),[42] followed by a recipe book,[43] or nutrient composition in the STFCJ.[20]

Determination of the *trans* fatty acid content of 526 foods

Determination was done in a 4-step process, as follows:

Step 1: Assigning analytic values reported in the literature

Trans fatty acid values in the analytic data[17–19,21–33] were converted to grams per 100 g of food, adjusting for total fat content in the STFCJ[20] using the following equation: *Trans* fatty acid (g)/100 g of food = [*trans* fatty acid (g)/total fat (g) in reference] × [total fat (g)/100 g of food in the STFCJ]. For any reference that reported the *trans* fatty acid value for a specific food as % fat without indicating the fat content (g/100 g) of the food, we used the fat content (g/100 g) provided in the STFCJ[20] to calculate the *trans* fatty acid value of the food.

We then considered a strategy to determine the *trans* fatty acid content of individual foods. Several articles analyzed the same type of food using the same method but provided different mean values. Discrepancies arose from variations in *trans* fatty acid content among food products. Also, most articles provided mean, minimum, and maximum values for analyzed products. In these cases, *trans* fatty acid content in individual foods might have been determined by choosing the highest or lowest mean value of multiple reports or by choosing the minimum or maximum value of the reports. To deal with these complexities, the following guidelines were applied.

1) When only 1 article existed and this article analyzed the *trans* fatty acid content in a single example of a food only, this value was selected ($n = 13$).

2) When only 1 article existed and this article analyzed the *trans* fatty acid content of several samples and reported

minimum, maximum, and/or mean values, we selected the mean value for the food ($n = 71$).

3) When multiple articles existed but reported different mean *trans* fatty acid values for a specific food, we calculated the mean value by weighting the number of foods analyzed in each article ($n = 59$).

Step 2: Assigning analytic values to similar foods

2-1A: When the *trans* fatty acid value for a specific food (except meat cuts) could not be obtained using Step 1, but an analytic value had been obtained (using Step 1) for a similar food within the same food category of the same food group, that value (*trans* fatty acid % of total fat) was assigned after comparison with nutrient content (total energy and macronutrients) in the STFCJ[20] ($n = 102$).

2-1B: When the *trans* fatty acid value for a specific food (except meat cuts) could not be obtained using Step 1, but an analytic value was available for a similar food within the same food group by Step 1, that value (*trans* fatty acid % of total fat) was assigned ($n = 78$).

2-2A: When the analytic *trans* fatty acid value of a specific meat cut was unavailable (Step 1), but an analytic value for the same part of the animal but with a different nutrient composition was, that value was assigned ($n = 22$).

2-2B: When the analytic *trans* fatty acid value of a specific meat cut was unavailable (Step 1), but an analytic value of a similar part of the animal having a similar nutrient composition was, that value was assigned ($n = 17$).

2-2C: When the analytic *trans* fatty acid value of a specific type of animal was unavailable (Step 1), but an analytic value of a similar type of animal having a similar nutrient composition and belonging to the same species was, that value was assigned ($n = 37$).

2-2D: When the analytic *trans* fatty acid value of a specific type of animal was unavailable (Step 1), but an analytic value of a different type of animal belonging to a different species was, that value was assigned ($n = 7$).

2-2E: When the analytic *trans* fatty acid value of a specific meat cut was unavailable (Step 1), but an analytic value of the same meat group was, that value was assigned ($n = 88$).

Step 3: Assigning values obtained from the ESHA Food Processor

For food products whose *trans* fatty acid values were unavailable using Steps 1 and 2, but for which a manufacturer was present in both Japan and the US, we compared the nutrient composition of the food in Japan, as shown on the website of the company, with that of the US, as provided in the ESHA Food Processor SQL, which covers more than 35 000 foods, including food products and fast foods sold in the US. The analytic nutrient values in ESHA databases were compiled from the latest US Department of Agriculture Standard Reference database, selected items from the Continuing Survey of Food Intakes by Individuals survey database, manufacturer data, data from fast food companies, and data from literature sources.[42] For foods whose nutrient compositions (total energy and macronutrients) were similar (eg, fast foods, cookies, and a cornflake product), we assigned the value obtained from the ESHA ($n = 14$).

Step 4: Assigning values estimated from recipes and nutrient compositions

When the *trans* fatty acid values for a specific food were unavailable using Steps 1–3, we then imputed values by referring to recipes[43] and the nutrient composition (total energy and macronutrients) of foods[20] ($n = 16$). Among 16 foods, 4 foods were found to contain *trans* fatty acids (roast beef, beef jerky, and 2 types of Japanese omelet).

A summary of the number of foods determined at each step is shown in Table 1.

Estimation of *trans* fatty acid intake among a Japanese population

Study population

The study was conducted between November 2002 and September 2003 in 4 areas in Japan: Osaka (Osaka City), Okinawa (Ginowan City), Nagano (Matsumoto City), and Tottori (Kurayoshi City). In each area, we first recruited apparently healthy women aged 30 to 69 years who were living together with their husbands and willing to participate with their husbands without consideration to their husband's age. Our recruitment strategy was to obtain 8 women for each 10-year age stratum (30–39 years, 40–49 years, 50–59 years, and 60–69 years). Before the study, the subjects attended group orientations, during which the study purpose and protocol were explained. Written informed consent was obtained from each subject. Body height was measured to the nearest 0.1 cm with the subject standing without shoes. Body weight in light indoor clothing was measured to the nearest 0.1 kg. Body mass index was calculated as body weight in kilograms divided by the square of body height in meters. A total of 121 women and 121 men completed the study protocol. For the analyses, we excluded women whose body weight was obviously mistyped in the database and men younger than 30 or older than 69 years ($n = 11$). Further, we excluded outliers of *trans* fatty acid intake, ie, those below or above the mean ± 3 standard deviations (g/day or % total energy), which left 119 women and 106 men aged 30 to 69 years for analysis.

Diet records

Subjects completed a 4-nonconsecutive-day semi-weighed DR for each season, at intervals of approximately 3 months: DR1 in November or December 2002 (autumn), DR2 in February 2003 (winter), DR3 in May 2003 (spring), and DR4 in August and September 2003 (summer). Each set of 4 recording days consisted of 1 weekend day and 3 weekdays. Details of the diet record procedure are provided elsewhere.[44] Briefly, during the orientation session, registered dietitians gave the subjects both written and verbal instructions on how to keep the DR, provided recording sheets and a digital scale, and asked them to record and weigh all foods and beverages

Table 1. Number of food items found to contain trans fatty acids

Food group[d]	Database development step[a,b,c]										
	1	2							3	4	Total
		1A	1B	2A	2B	2C	2D	2E			
Confectionaries (I)	25 (2)	49 (8)	34 (0)	0	0	0	0	0	2 (1)	12 (12)	122 (23)
Bakery (I)	6 (0)	12 (0)	9 (0)	0	0	0	0	0	1 (1)	0	28 (1)
Fats and oils (N)	11 (0)	2 (0)	6 (0)	0	0	0	0	0	0	0	19 (0)
Fats and oils (I)	5 (0)	0	0	0	0	0	0	0	0	0	5 (0)
Instant and retort foods (I)	17 (0)	26 (2)	0	0	0	0	0	0	0	0	43 (2)
Milk and dairy products (N)	23 (0)	13 (0)	8 (0)	0	0	0	0	0	0	0	44 (0)
Milk and dairy products (I)	7 (0)	0	0	0	0	0	0	0	0	0	7 (0)
Meat and meat products (N)	41 (0)	0	21 (0)	22 (0)	17 (0)	38 (0)	7 (0)	88 (0)	0	2 (0)	235 (0)
Margarine (I)	3 (0)	0	0	0	0	0	0	0	0	0	3 (0)
Fast foods (I)	1 (0)	0	0	0	0	0	0	0	10 (0)	0	11 (0)
Miscellaneous (I)	4 (0)	1 (0)	0	0	0	0	0	0	1 (0)	2 (0)	8 (0)
Total	143 (2)	103 (10)	78 (0)	22 (0)	17 (0)	38 (0)	7 (0)	88 (0)	14 (2)	16 (12)	526 (26)

(I) = industrially derived; (N) = naturally derived.

[a] Among a total of 1995 food items (ie, 1976 food items appearing in the Standard Tables of Food Composition in Japan[20] and 19 brand food items), 1469 foods [ie, others including confectionaries (*n* = 14); instant and retort foods (*n* = 4); milk and dairy products (*n* = 1); meat and meat products (*n* = 4); vegetables (*n* = 472); fruits (*n* = 120); sugar (*n* = 33); fish (*n* = 416); rice and grains (*n* = 88); noodles (*n* = 32); nuts and pulses (*n* = 108); seasonings (*n* = 66); eggs (*n* = 18); beverages (*n* = 92); miscellaneous (*n* = 1)] were determined to contain no trans fatty acids as they contained no or only trace amounts of fat, no partially hydrogenated oils, and no ruminant products.

[b] Step 1: foods determined by analytic values; Step 2: foods determined by assigning the value of a similar food obtained from Step 1 [ie, 1A (foods other than meat cuts): value of a similar food within the same food category of the same food group was assigned; 1B (foods other than meat cuts): value of a similar food within the same food group was assigned; 2A (meat cuts): value of the same cut but different nutrient composition was assigned; 2B (meat cuts): value of a similar cut having a similar nutrient composition was assigned; 2C (meat cuts): value of a similar type of animal having similar nutrient composition and belonging to the same species was assigned; 2D (meat cuts): value of a different type of animal belonging to a different species was assigned; 2E (meat cuts): value of a same meat group was assigned]; Step 3: foods determined using the ESHA Food Processor SQL; and Step 4: foods determined by recipe or nutrient composition.

[c] Numbers in parentheses are the number of food items determined to have zero trans fatty acids in Steps 1–4.

[d] Confectionaries (I) include cookies, biscuits, yeast doughnuts, pies, tarts, cakes, traditional Japanese sweets, potato chips, crackers, other Japanese snacks, and chocolate; bakery (I) includes bread (eg, white, whole, rye, and French), danish, pastry, and cake doughnuts; fats and oils (N) include butter, lard, and beef tallow; fats and oils (I) include mayonnaise, salad dressing, and vegetable oils; instant and retort foods (I) include instant cooking sauce (eg, curry roux and stew roux), retort foods (eg, retort curry, retort stew, retort Chinese sauce), frozen foods, instant soup (eg, powder soup and cube bouillon), and instant noodles (eg, cup noodles); milk and dairy products (N) include milk, cheese, yogurt, ice cream, and lactic acid drinks; milk and dairy products (I) include partially hydrogenated coffee creamer, partially hydrogenated powder coffee creamer, partially hydrogenated cream, and partially hydrogenated whip cream; meat and meat products (N) include beef and poultry (eg, chicken, pork, sausages, ham, and organ meats); margarine (I) includes soft-type margarine, shortening, and fat spread; fast foods (I) include french fries, hamburgers, chicken burgers, fish burgers, and fried chicken; and miscellaneous (I) includes a fish product (fish paste), a grain product (corn flake), tofu products (eg, fried tofu); and egg products (eg, omelets).

consumed on each recording day. All the collected records were checked by trained registered dietitians at the respective local center and then again at the study center.

A total of 1320 food and beverage items appeared in the DR. Intake of total energy and total fat were estimated based on the estimated intakes of all items and the STFCJ.[20] *Trans* fatty acid intake was estimated based on the database created in the present study. Regarding intake of fast foods, baked goods, and confectionaries in the DR, fewer than 1% of subjects reported that these foods were home-cooked. We therefore considered these foods to be commercial foods, and calculated their intake using *trans* fatty acid values of the food products themselves (eg, french fries) rather than those of the raw food materials (potatoes and oil). For foods containing refined oil, margarine, and shortening eaten at restaurants (eg, pork cutlet), nutrient information was unavailable. We therefore calculated the *trans* fatty acid intake of these foods by summing the amount reported for the raw food materials (pork and lard).

Statistical analyses

All statistical analyses were performed separately for women and men using SAS statistical software version 9.1 (SAS Institute Inc., Cary, NC, USA). We categorized subjects into 4 age groups (30–39 years, 40–49 years, 50–59 years, and 60–69 years). We also grouped subjects living in the 4 areas into 2 groups according to population density. Osaka (Osaka City: 11 743 persons/km^2) and Okinawa (Ginowan City: 4446 persons/km^2) had much higher population densities and were classified as urban; Nagano (Matsumoto City: 786 persons/km^2) and Tottori (Kurayoshi City: 285 persons/km^2) were classified as rural.[45] Because no significant seasonal variation in *trans* fatty acid intake was observed in any analysis by age group or residential area (data not shown), all analyses were performed using the 16-day mean dietary intake of the subjects. Total fat intake was expressed as grams per day and percentage of total energy intake. *Trans* fatty acid intake was expressed as grams per day, percentage of total energy intake, and percentage of total fat intake. Differences between the

Table 2. Characteristics of the 225 Japanese subjects

	Women (*n* = 119)			Men (*n* = 106)		
	Mean	SD	Range	Mean	SD	Range
Age (years)	49.7	11.1	30–69	50.4	10.8	30–69
Body height (cm)	154.6	6.2	132.5–170.7	168.0	6.4	150.0–186.0
Body weight (kg)	53.4	7.1	41.5–74.0	67.1	10.2	45.0–97.5
Body mass index (kg/m^2)	22.3	2.8	17.8–31.3	23.7	2.9	17.4–30.9
Total energy intake (kcal/day)	1847	289	1143–3034	2372	389	1413–3473
Total fat intake (g/day)	56.9	11.3	33.2–101.1	66.8	12.4	40.7–100.9
Total fat intake (% total energy)	27.7	3.4	18.9–35.1	25.5	3.5	17.9–34.6
Trans fatty acid intake (g/day)	1.7	0.7	0.4–4.1	1.7	0.6	0.6–3.5
Trans fatty acid intake (% total energy)	0.8	0.3	0.3–1.9	0.7	0.2	0.2–1.2
Trans fatty acid intake (% fat)	2.9	0.9	1.4–6.5	2.5	0.7	1.1–4.3

Abbreviation: SD = standard deviation.

urban and rural areas in total fat intake and *trans* fatty acid intake of subjects were examined using the non-paired *t*-test, while differences among age groups in total fat intake and *trans* fatty acid intake were determined using analysis of variance and the Tukey multiple comparison test. All reported *P* values are two-tailed, and a *P* value of <0.05 was considered statistically significant.

Table 3. Contribution (%) of selected food groups to total trans fatty acid intake among 225 Japanese subjects

Food Group[a]	Women (*n* = 119)		Men (*n* = 106)	
	Mean	SD	Mean	SD
Confectionaries (I)	21.7	19.7	15.3	25.0
Bakery (I)	19.1	13.3	18.0	13.7
Fats and oils (N)	2.0	2.0	2.1	2.4
Fats and oils (I)	14.1	6.0	20.0	7.4
Instant and retort foods (I)	7.5	6.4	10.0	8.3
Milk and dairy products (N)	12.3	8.2	9.7	7.9
Milk and dairy products (I)	3.3	4.1	3.1	5.1
Meat and meat products (N)	10.7	6.6	15.5	8.9
Margarine (I)	4.8	6.7	5.8	8.9
Fast foods (I)	3.5	7.0	3.7	8.8
Miscellaneous (I)	1.1	1.0	1.0	0.9

Abbreviation: SD = standard deviation; (I) = industrially derived; (N) = naturally derived.

[a]Food groups are defined in Table 1.

RESULTS

Subject characteristics are shown in Table 2. Mean total energy intake was 1847 kcal/day for women and 2372 kcal/day for men. Mean total fat intake was 56.9 g/day (27.7% total energy) for women and 66.8 g/day (25.5% total energy) for men. Mean *trans* fatty acid intake was 1.7 g/day (0.8% total energy) for women and 1.7 g/day (0.7% total energy) for men.

Major contributors to *trans* fatty acid intake were confectionaries, baked goods, and fats and oils. Approximately 75% of intake was attributable to industrially produced *trans* fatty acids (Table 3).

Mean total fat intake in urban subjects was significantly higher than that in rural subjects (women: 28.8% total energy vs 26.8% total energy, *P* = 0.001; men: 26.6% total energy vs 24.4% total energy, *P* = 0.001), as was mean *trans* fatty acid intake (women: 0.9% total energy vs 0.7% total energy, *P* = 0.004; men: 0.7% total energy vs 0.6% total energy, *P* = 0.004) (Table 4).

Table 5 shows mean total fat and *trans* fatty acid intake by age group. Subjects aged 30–39 years had the highest mean total fat and *trans* fatty acid intake (women: 29.1% total energy and 1.0% total energy; men: 27.5% total energy and 0.8% total

Table 4. Total fat and trans fatty acid intake of 225 Japanese subjects living in urban and rural areas[a] of Japan

	Women (*n* = 119)					Men (*n* = 106)				
	Urban (*n* = 57)		Rural (*n* = 62)		*P*[b]	Urban (*n* = 51)		Rural (*n* = 55)		*P*[b]
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Total energy (kcal/day)	1803	306	1888	268	0.11	2310	371	2436	400	0.11
Total fat (g/day)	57.7	11.8	56.2	10.8	0.47	68.0	12.0	65.8	12.7	0.36
Total fat (% total energy)	28.8	3.0	26.8	3.5	0.001	26.6	3.5	24.4	3.2	0.001
Trans fatty acid (g/day)	1.8	0.8	1.6	0.6	0.03	1.9	0.7	1.6	0.6	0.04
Trans fatty acid (% total energy)	0.9	0.3	0.7	0.3	0.004	0.7	0.2	0.6	0.2	0.004
Trans fatty acid (% fat)	3.1	1.0	2.7	0.8	0.02	2.7	0.8	2.4	0.6	0.049

Abbreviation: SD = standard deviation.

[a]According to population density,[45] 4 residential areas were grouped into urban (Osaka and Okinawa) and rural (Nagano and Tottori) areas.

[b]Differences between subjects in the 2 areas were tested by the unpaired *t*-test.

Table 5. Total fat and trans fatty acid intake of 225 Japanese subjects according to age group

	Women (n = 119)									Men (n = 106)								
	30–39 years (n = 27)		40–49 years (n = 29)		50–59 years (n = 32)		60–69 years (n = 31)		P^{e}	30–39 years (n = 20)		40–49 years (n = 29)		50–59 years (n = 28)		60–69 years (n = 29)		P^{e}
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Total energy																		
(kcal/day)	1879	384	1816	289	1849	215	1847	270	0.82	2241	303	2454	450	2454	382	2302	360	0.85
Total fat																		
(g/day)	60.6^{a}	13.1	$58.8^{a,b}$	12.4	$55.0^{a,b}$	9.6	54.0^{b}	9.3	0.01	68.5^{a}	10.4	69.3^{a}	14.1	69.4^{a}	12.7	60.8^{a}	9.5	0.02
(% total energy)	29.1^{a}	2.9	$29.0^{a,b}$	2.9	$26.7^{a,b}$	3.1	26.7^{b}	3.1	<0.001	27.5^{a}	2.1	$25.6^{b,c,d}$	4.1	$25.6^{b,c,d}$	3.7	$23.9^{b,c,d}$	2.7	<0.001
Trans fatty acid																		
(g/day)	$2.1^{a,b,c}$	0.8	$1.9^{a,b,c}$	0.8	$1.7^{a,b,c}$	0.6	1.2^{d}	0.4	<0.001	$1.9^{a,b,c}$	0.5	$1.9^{a,b,c}$	0.7	$1.7^{a,b,c}$	0.6	1.4^{d}	0.5	0.001
(% total energy)	$1.0^{a,b}$	0.3	$0.9^{a,b,c}$	0.3	$0.8^{b,c}$	0.2	$0.6^{c,d}$	0.2	<0.001	$0.8^{a,b}$	0.2	$0.7^{a,b,c}$	0.2	$0.6^{b,c}$	0.2	$0.6^{c,d}$	0.2	<0.001
(% fat)	$3.4^{a,b,c}$	1.0	$3.2^{a,b,c}$	0.8	$3.0^{a,b,c}$	0.8	2.2^{d}	0.6	<0.001	$2.8^{a,b,c}$	0.6	$2.7^{a,b,c}$	0.7	$2.4^{a,b,c}$	0.6	2.4^{d}	0.8	0.007

Abbreviation: SD = standard deviation.

[a,b,c,d] Values in the same row, but with different superscripts, are significantly different: $P < 0.05$ (Tukey multiple comparison test).

[e] Differences between age groups were tested by analysis of variance.

Table 6. Distribution of trans fatty acid intake among 225 Japanese subjects[a]

	By living area				By age group								Total	
	Urban		Rural		30–39 years		40–49 years		50–59 years		60–69 years			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Women	57	100	62	100	27	100	29	100	32	100	31	100	119	100
Trans fatty acid (g/day)														
0.47–0.99	4	7.0	11	17.7	0	0	1	3.4	2	6.3	12	38.7	15	12.6
1.00–1.49	16	28.1	24	38.7	6	22.2	10	34.5	10	31.3	14	45.2	40	33.6
1.50–1.99	18	31.6	16	25.8	11	40.7	6	20.7	13	40.6	4	12.9	34	28.6
2.00–2.49	7	12.3	5	8.1	2	7.4	4	13.8	6	18.8	0	0	12	10.1
2.50–2.99	4	7.0	5	8.1	4	14.8	4	13.8	0	0	1	3.2	9	7.6
3.00–4.08	7	12.3	2	3.2	4	14.8	4	13.8	1	3.1	0	0	9	7.6
Trans fatty acid (% total energy)														
0.31–0.49	3	5.3	11	17.7	0	0	0	0	3	9.4	11	35.5	14	11.8
0.50–0.74	16	28.1	27	43.5	6	22.2	12	41.4	10	31.3	15	48.4	43	36.1
0.75–0.99	18	31.6	15	24.2	12	44.4	6	20.7	11	34.4	4	12.9	33	27.7
1.00–1.24	11	19.3	4	6.5	5	18.5	4	13.8	6	18.8	0	0	15	12.6
1.25–1.49	6	10.5	4	6.5	2	7.4	5	17.2	2	6.3	1	3.2	10	8.4
1.50–1.95	3	5.3	1	1.6	2	7.4	2	6.9	0	0	0	0	4	3.4
Men	51	100	55	100	20	100	29	100	28	100	29	100	106	100
Trans fatty acid (g/day)														
0.68–0.99	6	11.8	5	9.1	0	0	0	0	5	17.9	6	20.7	11	10.4
1.00–1.49	13	25.5	21	38.2	4	20.0	11	37.9	7	25.0	12	41.4	34	32.1
1.50–1.99	12	23.5	19	34.5	7	35.0	9	31.0	9	32.1	6	20.7	31	29.2
2.00–2.49	9	17.6	6	10.9	6	30.0	4	13.8	3	10.7	2	6.9	15	14.2
2.50–2.99	7	13.7	2	3.6	2	10.0	1	3.4	3	10.7	3	10.3	9	8.5
3.00–3.49	4	7.8	2	3.6	1	5.0	4	13.8	1	3.6	0	0	6	5.7
Trans fatty acid (% total energy)														
0.20–0.49	10	19.6	17	30.9	0	0	8	27.6	7	25.0	12	41.4	27	25.5
0.50–0.74	20	39.2	27	49.1	9	45.0	9	31.0	16	57.1	13	44.8	47	44.3
0.75–0.99	15	29.4	11	20.0	9	45.0	9	31.0	5	17.9	3	10.3	26	24.5
1.00–1.23	6	11.8	0	0	2	10.0	3	10.3	0	0	1	3.4	6	5.7

[a] According to population density,[45] 4 residential areas were grouped into urban (Osaka and Okinawa) and rural (Nagano and Tottori) areas.

energy), followed by those aged 40–49 years, 50–59 years, and 60–69 years ($P < 0.001$). The Tukey t-test revealed that the mean total fat intake of women (% total energy) aged 30–39 years was significantly higher than that of women aged 60–69 years ($P < 0.05$). *Trans* fatty acid intake of both women and men aged 30–39 years was significantly higher than that of those aged 50–59 years and 60–69 years ($P < 0.05$), while the intake of women aged 40–49 years was significantly higher than that of those aged 60–69 years ($P < 0.05$).

The distribution of *trans* fatty acid intake among 225 Japanese subjects is shown in Table 6. Twenty-four percent of women (n = 29) and 6% of men (n = 6) showed a mean intake of more than 1% of total energy intake. By area of residence, the frequency of *trans* fatty acid intake greater than 1% of total energy intake was higher among women living in urban areas (35%; $n = 20$) than in those living in rural areas (15%; $n = 9$). Among men, the frequency of *trans* fatty acid intake greater than 1% of total energy intake was higher in those living in urban areas (12%; $n = 6$) than in those living in rural areas (0%; $n = 0$). By age group, the frequency of *trans* fatty acid intake greater than 1% of total energy intake among women was higher in younger age groups: 30–39 years, 33% ($n = 9$); 40–49 years, 38% ($n = 11$); 50–59 years, 25% ($n = 8$); 60–69 years, 3% ($n = 1$). Among men, the frequency of *trans* fatty acid intake greater than 1% of total energy intake was similar among age groups: 30–39 years, 10% ($n = 2$); 40–49 years, 10% ($n = 3$); 50–59 years, 0% ($n = 0$); 60–69 years, 3% ($n = 1$).

Furthermore, we compared estimated *trans* fatty acid intake based on a database containing 1995 foods (1976 foods appearing in the STFCJ[20] and 19 added foods) and that based on a database containing 1976 foods appearing in the STFCJ[20] (without the addition of the 19 foods) to investigate the impact of these 19 foods. The mean *trans* fatty acid intake (g/day) calculated using the databases containing 1976 foods and 1995 foods was 1.5 g/day vs 1.7 g/day for women and 1.6 g/day vs 1.7 g/day for men. The mean *trans* fatty acid intake (% total energy) calculated using the databases containing 1976 foods and 1995 foods was 0.7% total energy vs 0.8% total energy for women and 0.6% total energy vs 0.7% total energy for men.

DISCUSSION

We found that mean *trans* fatty acid intake was 0.8% of total energy among Japanese women and 0.7% of total energy among Japanese men. Twenty-four percent of women and 6% of men had a mean intake of more than 1% of total energy intake, the maximum recommended by the WHO[6]; the frequency was particularly high in women living in urban areas and in subjects aged 30–39 and 40–49 years.

The estimated mean *trans* fatty acid intake from 3 previous studies using oil production data or household data in Japan was 1.6[16] and 1.8 g/capita/day[17] (oil production data) and 0.7 g/day (household data).[18] These studies did not include important foods containing *trans* fatty acids (ie, retort foods, fast foods, shortening, poultry, and traditional Japanese confectionaries). Three other studies using 24-hour recall or a diet record at a single point in time reported an estimated mean intake of 0.3 and 1.0 g/day,[15,18,19] or 0.03% to 0.5% total energy[14,15,19]; however, in 1 study the selection and number of foods included in the database were not reported,[14] in 2 studies the database was not developed specifically for Japanese populations and the number of foods included in the database was limited,[15,19] and in 2 studies the sample size was small ($n = 8$; $n = 25$).[15,19] One of these studies measured the 1-day diet (7-day diet records were initially collected and measurement was done for 1 of the 7 days) of 25 female students at a dietetic college, and yielded an intake estimate of 1.2 g/day (0.6% total energy).[19] This result was lower than the present estimate, possibly due to differences in eating patterns between groups, given that important sources of *trans* fatty acids in the 7-day mean food group intake differed from those reported our subjects (pastry: 6.1 g vs 14.9 g in the present study; instant ramen noodles: 0.8 g vs 9.8 g; beef and organ meats: 9.9 g vs 17.0 g; milk and milk products: 184.0 g vs 145.7 g; margarine: 0.3 g vs 1.9 g; other fats and oils: 12.8 g vs 15.1 g; and confectionaries: 36.3 g vs 46.1 g). Further, the nutritional knowledge of subjects in the previous study may have influenced their eating habits.

The estimated mean *trans* fatty acid intake in the present subjects was within the range of estimated mean intake of residents of Western countries—1.2 to 7.1 g/day (0.5%–4.9% total energy)[1–5,46–52]—but relatively low. This difference in estimates may be due to the use of different databases with a limited numbers of foods, different dietary assessment methods, and/or different dietary habits. Regarding dietary sources of *trans* fatty acids, the contribution of industrially produced *trans* fatty acids in our subjects was approximately 75%, whereas that in Western countries ranged from 23% to 74%, although data on dietary sources were not available for all studies.[3–5,49–52] This result indicates that the intake of industrially produced *trans* fatty acids (% total energy) in our subjects was comparable with that of most Western countries that have reported estimates,[1,2,46–48] although the total *trans* fatty acid intake of our subjects was relatively low.

We acknowledge several limitations of our study. First, analytic *trans* fatty acid values were not available for all foods within a particular type, and variation in values occurred among food products within the same food group.[35] In addition, although we added several foods which are important sources of *trans* fatty acids (ie, fast foods, baked goods, and confectionaries) to the database, these added foods do not represent all food products on the market. This limited the completeness of the database and, therefore, the assessment of *trans* fatty acid intake. Nevertheless, we were able to obtain all relevant data available from sources with suitably clear and comprehensive assessment methodologies, to carefully conduct matching processes for foods with similar food values, and to follow a similar process to that used in previous Western studies,[49,53] which used standardized procedures[54] to ensure database reliability. The mean *trans* fatty acid intake calculated with the database of 1976 foods (foods appearing in the STFCJ[20]) for women and men was 0.2 g/day (13%) or 0.1% total energy (14%) and 0.1 g/day (6%) or 0.1% total energy (17%), respectively; these values were lower than those calculated using the database of 1995 foods. In contrast, the use of the 2 databases to calculate % total energy yielded very similar values, indicating that the addition of a number of foods into the food composition database had a negligible effect when intake was expressed as % total energy. Second, although the use of diet records allows detailed assessment of the dietary intake of individuals, the self-reported dietary assessment method is subject to measurement error. Finally, our subjects were volunteers and, hence, not a representative sample of the general Japanese population. They may therefore have been more nutritionally conscious than others who did not participate in the study, and our results may thus not be generalizable to the entire Japanese population.

In conclusion, although mean *trans* fatty acid intake was below the maximum intake recommended by the WHO, the intakes of subgroups, especially women living in urban areas and people aged 30–39 and 40–49 years, was of concern. Further public health efforts to reduce *trans* fatty acid intake should be encouraged.

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REFERENCES

1. Mozaffarian D, Katan MB, Ascherio A, Stampfer MJ, Willett WC. Trans fatty acids and cardiovascular disease. N Engl J Med. 2006;354:1601–13.
2. Willett WC, Stampfer MJ, Manson JE, Colditz GA, Speizer FE, Rosner BA, et al. Intake of *trans* fatty acids and risk of coronary heart disease among women. Lancet. 1993;341:581–5.
3. Pietinen P, Ascherio A, Korhonen P, Hartman AM, Willett WC, Albanes D, et al. Intake of fatty acids and risk of coronary heart disease in a cohort of Finnish men. The Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study. Am J Epidemiol. 1997;145:876–87.
4. Chardigny JM, Destaillats F, Malpuech-Brugère C, Moulin J, Bauman DE, Lock AL, et al. Do *trans* fatty acids from industrially produced sources and from natural sources have the same effect on cardiovascular disease risk factors in healthy subjects? Results of the *trans* Fatty Acids Collaboration (TRANSFACT) study. Am J Clin Nutr. 2008;87:558–66.
5. Jakobsen MU, Overvad K, Dyerberg J, Heitmann BL. Intake of ruminant *trans* fatty acids and risk of coronary heart disease. Int J Epidemiol. 2008;37:173–82.
6. World Health Organization. Diet, Nutrition and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consultation. WHO Technical Report Series no. 916. Geneva: WHO; 2008.
7. Nijman CA, Zijp IM, Sierksma A, Roodenburg AJ, Leenen R, van den Kerkhoff C, et al. A method to improve the nutritional quality of foods and beverages based on dietary recommendations. Eur J Clin Nutr. 2007;61:461–71.
8. Astrup A. The *trans* fatty acid story in Denmark. Atheroscler Suppl. 2006;7:43–6.
9. Spaaij CJ, Pijls LT. New dietary reference intakes in the Netherlands for energy, proteins, fats and digestible carbohydrates. Eur J Clin Nutr. 2004;58:191–4.
10. Moss J. Labeling of *trans* fatty acid content in food, regulations and limits-the FDA view. Atheroscler Suppl. 2006;7:57–9.
11. Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington: IOM; 2002.
12. U.S Department of Agriculture. Fat and fatty acid content of selected foods containing *trans* fatty acids. Beltsville: U.S. Department of Agriculture; 2004.
13. Satchithanandam S, Oles CJ, Spease CJ, Brandt MM, Yurawecz MP, Rader JI. *Trans*, saturated, and unsaturated fat in foods in the united states prior to mandatory *trans*-fat labeling. Lipids. 2004;39:11–8.
14. Zhou BF, Stamler J, Dennis B, Moag-Stahlberg A, Okuda N, Robertson C, et al; INTERMAP Research Group. Nutrient intakes of middle-aged men and women in China, Japan, United Kingdom, and United States in the late 1990s: the INTERMAP study. J Hum Hypertens. 2003;17:623–30.
15. Kromhout D, Menotti A, Bloemberg B, Aravanis C, Blackburn H, Buzina R, et al. Dietary saturated and *trans* fatty acids and cholesterol and 25-year mortality from coronary heart disease: the Seven Countries Study. Prev Med. 1995;24:308–15.
16. Okamoto T, Matsuzaki H, Maruyama T, Niiya I, Sugano M. *Trans* fatty acid content in hydrogenated oils and estimated intake. J Jpn Oil Chem Soc. 1999;48:1411–4 (in Japanese).
17. Okamoto T, Kinoshita Y, Kanematsu H, Niiya I, Sugano M. *Trans*-fatty acid contents of various foods cooked with oils and fats in Japan. J Jpn Oil Chem Soc. 1993;42:996–1001 (in Japanese).
18. Cabinet of Japan Food Safety Committee. Evaluative report on *trans* fatty acid content in foods: Total confirmation assessment in 2006. Tokyo: Cabinet of Japan Food Safety Committee; 2007 (in Japanese).
19. Kawabata T, Hyogo H, Hagiwara C, Matsuzaki S, Shinjo S. Intake of *trans* fatty acids estimated by direct dietary measurement in young women. J Jpn Soc Nutr Food Sci. 2008;61:161–8 (in Japanese).
20. Science and Technology Agency. Standard Tables of Food Composition in Japan, 5th ed., Tokyo: Printing Bureau of the Ministry of Finance; 2005 (in Japanese).
21. Sugahara R, Okamoto T, Chimi K, Maruyama T, Sugano M. *Trans* fatty acid content in Japanese Commercial Margarines. J Oleo Sci. 2006;55(2):59–64.
22. Matsuzaki H, Aoyama M, Baba A, Maruyama T, Niiya I, Yanagita T, et al. Study of *trans* fatty acid content in Commercial Foods in Japan: I Domestic milk. J Oleo Sci. 1998;47:45–50 (in Japanese).
23. Matsuzaki H, Aoyama M, Baba A, Maruyama T, Niiya I, Yanagita T, et al. Study of *trans* fatty acid content in Commercial Foods in Japan: II Butter, cheese, and other dairy products. J Jpn Oil Chem Soc. 1998;47:345–9 (in Japanese).
24. Matsuzaki H, Aoyama M, Baba A, Maruyama T, Niiya I, Yanagita T, et al. Study of *trans* fatty acid content in Commercial Foods in Japan: III Meat and meat products. J Jpn Oil Chem Soc. 1998;47:495–9 (in Japanese).
25. Matsuzaki H, Aoyama M, Baba A, Maruyama T, Niiya I, Yanagita T, et al. Study of *trans* fatty acid content in Commercial Foods in Japan: IV Roux, Retort foods and soup. J Jpn Oil Chem Soc. 1999;48:787–91 (in Japanese).
26. Matsuzaki H, Aoyama M, Baba A, Maruyama T, Niiya I, Yanagita T, et al. Study of *trans* fatty acid content in Commercial

Foods in Japan: V Foreign-made confectionery. J Jpn Oil Chem Soc. 2000;49:625–30 (in Japanese).

27. Matsuzaki H, Aoyama M, Baba A, Maruyama T, Niiya I, Yanagita T, et al. Study of *trans* fatty acid content in Commercial Foods in Japan: VI Chocolate and chocolate confectionery. J Jpn Oil Chem Soc. 2001;50:49–55.
28. Matzuzaki H, Ohta C, Kinoshita Y, Maruyama T, Niiya I, Sugano M. *Trans* fatty acid content of margarines in Portugal, Belgium, Netherlands, United States, and Japan. J Jpn Oil Chem Soc. 1998;47:195–9 (in Japanese).
29. Matzuzaki H, Aoyama M, Maruyama T, Niiya I, Yanagita T, Sugano M. *Trans* fatty acids in margarines marketed in eleven countries. J Oleo Sci. 2002;51:555–61.
30. Okamoto T, Tsutsumi T, Tokairin S, Ehara H, Maruyama T, Niiya I, et al. Formation of *trans*-fatty acids during vegetable oil refining and *trans*-fatty acid content in refined edible oils. J Jpn Oil Chem Soc. 1999;48:877–83.
31. Ochi T, Kinoshita Y, Ota C, Maruyama T, Niiya I, Sugano M, et al. Comparison of *trans*-fatty acid compositions in imported and domestic baked confectioneries. J Jpn Oil Chem Soc. 1996;45:275–83.
32. Koga T. *Trans* fatty acids of Commercial confectionaries. Nakamura Gakuen University Journal. 1992;24:85–8 (in Japanese).
33. Safety of our foods and life. *Trans* fatty acids. Tokyo: Nonprofit organization, Japan Offspring Fund; 2005 (in Japanese).
34. AOAC Official Method. Fat (total, saturated, and unsaturated) in foods, hydrolytic extraction gas chromatographic method. In: Horwitz W (ed). Official Methods of Analysis of AOAC International, 18th ed. Illinois: AOAC INTERNATIONAL; 2001.
35. Innis SM, Green TJ, Halsey TK. Variability in the *trans* fatty acid content of foods within a food category: implications for estimation of dietary *trans* fatty acid intakes. J Am Coll Nutr. 1999;18:255–60.
36. Aro A, Van Amelsvoort J, Becker W, Van Erp-Baart MA, Kafatos A, Leth T, et al. *Trans* fatty acids in dietary fats and oils from 14 European countries: the TRANSFAIR Study. J Food Compost Anal. 1998;11:137–49.
37. Aro A, Antoine JM, Pizzoferrato L, Reykdal O, Van Poppel G. *Trans* fatty acids in dairy and meat products from 14 European countries: the TRANSFAIR Study. J Food Compost Anal. 1998;11:150–60.
38. Aro A, Amaral E, Kesteloot H, Rimestad A, Thamm M, Van Poppel G. *Trans* fatty acids in French fries, soups and snacks from 14 European countries: the TRANSFAIR Study. J Food Compost Anal. 1998;11:170–7.
39. Van Erp-Baart MA, Couet C, Cuadrado C, Kafatos A, Stanley J, Van Poppel G. *Trans* fatty acids in bakery products from 14 European countries: the TRANSFAIR Study. J Food Compost Anal. 1998;11:161–9.
40. Nikkei net [homepage on the Internet]. Tokyo: Nikkei Inc.; [updated 2007 May 11; cited 2008 April 1]. Available from: http://www.nikkei.co.jp/report/inshoku/20070611a6a6b000_11.html.
41. The Japan Food Newspaper. Trends of food products 2006–2007, general edition. Tokyo: The Japan Food Newspaper; 2006 (in Japanese).
42. ESHA Research. The Food Processor SQL; Nutrition and fitness software. Salem: OR; 2005.
43. Kagawa A. Basic data for cooking. 16th ed. Tokyo: Kagawa Women Nutrition University Press; 1995 (in Japanese).
44. Murakami K, Sasaki S, Takahashi Y, Okubo H, Hirota N, Notsu A, et al. Reproducibility and relative validity of dietary glycaemic index and load assessed with a self-administered diet-history questionnaire in Japanese adults. Br J Nutr. 2008;99:639–48.
45. Ministry of Public Management, Home Affairs, Posts and Telecommunications. Japan National Census, 2000: Statistical tables according to prefectures, cities, city blocks, and villages, 2000 (in Japanese).
46. Hulshof KF, van Erp-Baart MA, Anttolainen M, Becker W, Church SM, Couet C, et al. Intake of fatty acids in western Europe with emphasis on *trans* fatty acids: the TRANSFAIR Study. Eur J Clin Nutr. 1999;53:143–57.
47. Cantwell MM, Flynn MA, Cronin D, O'Neill JP, Gibney MJ. Contribution of foods to *trans* unsaturated fatty acid intake in a group of Irish adults. J Hum Nutr Diet. 2005;18:377–85, quiz 387–9.
48. Bolton-Smith C, Woodward M, Fenton S, McCluskey MK, Brown CA. *Trans* fatty acids in the Scottish diet. An assessment using a semi-quantitative food-frequency questionnaire. Br J Nutr. 1995;74:661–70.
49. Allison DB, Egan SK, Barraj LM, Caughman C, Infante M, Heimbach JT. Estimated intakes of *trans* fatty and other fatty acids in the US population. J Am Diet Assoc. 1999;99:166–74, quiz 175–6.
50. Oomen CM, Ocké MC, Feskens EJ, Kok FJ, Kromhout D. α-Linolenic acid intake is not beneficially associated with 10-y risk of coronary artery disease incidence: the Zutphen Elderly Study. Am J. Clin Nutr. 2001;74:457–63.
51. Akesson B, Johansson BM, Svensson M, Ockerman PA. Content of *trans*-octadecenoic acid in vegetarian and normal diets in Sweden, analyzed by the duplicate portion technique. Am J Clin Nutr. 1981;34:2517–20.
52. Flood VM, Webb KL, Rochtchina E, Kelly B, Mitchell P. Fatty acid intakes and food sources in a population of older Australians. Asia Pac J Clin Nutr. 2007;16:322–30.
53. Schakel SF, Harnack L, Wold C, Van Heel N, Himes JH. Incorporation of *trans*-fatty acids into a comprehensive nutrient database. J Food Compost Anal. 1999;12:323–31.
54. Schakel S, Buzzard I, Gebhardt S. Procedures for estimating nutrient values for food composition databases. J Food Compost Anal. 1997;10:102–14.

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Estimation of caffeine intake in Japanese adults using 16 d weighed diet records based on a food composition database newly developed for Japanese populations

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Abstract

Objective: Previous studies in Western populations have linked caffeine intake with health status. While detailed dietary assessment studies in these populations have shown that the main contributors to caffeine intake are coffee and tea, the wide consumption of Japanese and Chinese teas in Japan suggests that sources of intake in Japan may differ from those in Western populations. Among these teas, moreover, caffeine content varies widely among the different forms consumed (brewed, canned or bottled), suggesting the need for detailed dietary assessment in estimating intake in Japanese populations. Here, because a caffeine composition database or data obtained from detailed dietary assessment have not been available, we developed a database for caffeine content in Japanese foods and beverages, and then used it to estimate intake in a Japanese population.
Design: The caffeine food composition database was developed using analytic values from the literature, 16 d weighed diet records were collected, and caffeine intake was estimated from the 16 d weighed diet records.
Setting: Four areas in Japan, Osaka (Osaka City), Okinawa (Ginowan City), Nagano (Matsumoto City) and Tottori (Kurayoshi City), between November 2002 and September 2003.
Subjects: Two hundred and thirty Japanese adults aged 30–69 years.
Results: Mean caffeine intake was 256·2 mg/d for women and 268·3 mg/d for men. The major contributors to intake were Japanese and Chinese teas and coffee (47 % each). Caffeine intake above 400 mg/d, suggested in reviews to possibly have negative health effects, was seen in 11 % of women and 15 % of men.
Conclusions: In this Japanese population, caffeine intake was comparable to the estimated values reported in Western populations.

Keywords
Food composition database
Caffeine
Japanese population

Caffeine, 1,3,7-trimethylxanthine, occurs naturally in the leaves, seeds and fruits of more than sixty plants, including coffee beans and tea leaves, and has long been consumed in the form of coffee, black tea, green tea and cocoa(1,2). Caffeine is also used as an additive in products such as energy drinks, soft drinks and sweets(1–3). Caffeine appears to have stimulatory effects, particularly on the central nervous system, via its activity as an adenosine receptor antagonist(2,4–6). Although findings are not consistent, high caffeine intake has been associated with adverse health outcomes, including high blood pressure, osteoporosis and spontaneous abortion(5–7). Moderate intake has also been associated with several health benefits, including the prevention of type 2 diabetes and

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Parkinson's disease(6). Further, a long-term increase in caffeine intake was associated with a smaller weight gain(8). Reviews on the effect of caffeine intake on health status in 2003 and 2006 concluded that while moderate intake among adults (up to 400 mg/d) may have no negative effect on health status, women of reproductive age should limit intake to below 300 mg/d(5,6) or 4·6 mg/kg body weight per d(5). Several committees, including the European Union Scientific Committee on Food (1999) and Health Canada (2003), have advised women of reproductive age to keep caffeine intake below 300 mg/d(9,10). Recently, the UK Food Standards Agency (2008) decreased its recommended limit from 300 to 200 mg/d(11).

Several Western studies of caffeine intake among individuals which used detailed dietary assessment methods (e.g. 24 h recall and diet record) reported mean estimated intakes ranging from 173·9 to 490·0 mg/d (1·9 to 7·0 mg/kg body weight per d)(1,12–15), obtained mainly from coffee(1,13–15) or black tea(1,12). In Japan, in contrast, the main beverages both at and between meals are Japanese and Chinese teas, including green tea and oolong tea(16,17), suggesting that sources and amounts of caffeine intake may differ from those in Western populations. In addition, caffeine content in the different forms of beverages consumed in Japan (brewed, canned or polyethylene terephthalate (PET)-bottled) are reported to vary widely(16,18–39), further emphasizing the need for detailed dietary assessment among Japanese populations. Although any investigation into the effects of caffeine on the health status of specific populations should begin with the estimation of caffeine intake in that population, data on the caffeine intake of individuals estimated by detailed diet assessment methods in Japan are lacking.

Here, we developed a caffeine database which considered the types and forms of both beverages and foods, and then estimated caffeine intake among a Japanese population using 16 d weighed diet records (DR).

Methods

Development of a caffeine database

Data sources and number of beverage and food items

We developed a caffeine database which accounted for important caffeine-containing beverages and foods in various forms, as follows. First, we searched the PubMed, CiNii, Medical Online Library and Ichushi Web databases for English and Japanese papers reporting analyses of the caffeine content of beverages and foods conducted in Japan. We reviewed the abstracts and reference lists of all relevant articles and selected articles which assessed the caffeine contents in beverages and foods in Japan (*n* 53). We included data in the *Standard Tables of Food Composition in Japan*(16) as one of the references. We then selected reports which assessed caffeine content by HPLC and gave sufficient explanation of the assessment methods used. This process identified twenty-three reports(16,18–39) for consideration in the development of the present database.

Using the data in the reports, we then created the database, as follows. Since the *Standard Tables of Food Composition in Japan*(16) is considered to cover major beverages and foods consumed in Japan (*n* 1976), we first selected beverages and foods made with plant varieties possibly containing caffeine(1–3,5,6,40) from items in the *Standard Tables of Food Composition in Japan*(16) (*n* 26). However, these tables include coffee, black tea, and Japanese and Chinese teas in dry and brewed forms only; given the wide variation in caffeine contents in different forms of beverages (brewed, canned or PET-bottled) in Japan(16,18–39), we also added beverages in canned or PET-bottled forms (*n* 23). We then added other beverages and foods made with plant varieties possibly containing caffeine and reported in the DR but not shown in the tables (*n* 6). As supplemental information, we also added other items whose caffeine values were provided in the analytic reports but which were not listed in the DR or tables (*n* 25). In total, we covered eighty items (fifty-nine beverages and twenty-one foods).

Determination of caffeine content for eighty beverages and foods

Caffeine values in the analytic data were standardized to milligrams per 100 grams (mg/100 g)(16). For several reports which assessed content in brewed coffee, brewed Japanese and Chinese teas, or canned or PET-bottled beverages as milligrams per 100 millilitres (mg/100 ml), we compared caffeine contents in mg/100 ml and mg/100 g using the ESHA Food Processor SQL, obtained approximate conversion factors (e.g. 0·96 for canned or PET-bottled black tea with lemon, 1·002 for brewed coffee, 1·001 for brewed Japanese and Chinese teas, and 1·04 for canned or PET-bottled cola), and converted them to mg/100 g.

We then considered a strategy to determine the caffeine content of individual items. Several reports analysed the same type of beverages and foods using the same method but provided different mean values. For these, we applied the following guidelines, with determination done in a two-step process, as follows.

1. *Step 1: Assigning analytic values reported in the literature.*
   (a) When only one report existed and this report analysed the caffeine content in a single example of a beverage or food only, this value was selected (*n* 13).
   (b) When multiple reports existed, we calculated the mean value by weighting the number of items analysed in each report (*n* 57). For example, four reports analysed canned or PET-bottled black tea (*n* 33) and showed mean values per 100 g of 13·4 mg (*n* 5)(18), 13·5 mg (*n* 5)(28), 17·0 mg (*n* 19)(29) and

14·6 mg (n 4)[39]. The weighted mean value of thirty-three samples (15·6 mg/100 g) was thus selected as the value for canned or PET-bottled black tea (i.e. 13·4 × 5/33 + 13·5 × 5/33 + 17·0 × 19/33 + 14·6 × 4/33). Some reports did not indicate the number of samples analysed[16,19]; these were excluded when calculating the mean from multiple reports since the calculation of mean required the number of samples be known.

2. *Step 2: Assigning analytic value of a similar beverage or food within the same category.*

   When a caffeine value for specific beverages or foods could not be obtained using Step 1 but the analytic value of a similar item was available, that value was assigned (n 10). The value for canned or bottled *sencha* was assigned to canned or bottled *kamairicha*, *bancha* and *tamaryokucha*; that for the dry type of *hojicha* was assigned to the dry type of *genmaicha*; that for the dry type of *bancha* was assigned to the dry type of blend Japanese and Chinese tea; that for the brewed type of *bancha* was assigned to the brewed type of blend Japanese and Chinese tea; that for the canned or bottled type of oolong tea was assigned to the canned or bottled type of *pu-erh* tea; that for pure cocoa powder was assigned to that for milk cocoa powder; that for soda was assigned to fruit-flavoured soda; and that for chocolate cake was assigned to coffee cake.

Caffeine values were determined using either Step 1 or 2 for all eighty items. A summary of the caffeine content of beverages and foods as well as the definitions of some beverages are shown in Table 1.

Estimation of caffeine intake among a Japanese population

Study population

The study was conducted between November 2002 and September 2003 in four areas in Japan: Osaka (Osaka City), Okinawa (Ginowan City), Nagano (Matsumoto City) and Tottori (Kurayoshi City). In each area, we first recruited apparently healthy women aged 30–69 years who were living with and willing to participate with their husbands, without consideration to the husband's age. Our recruitment strategy was to obtain eight women for each 10-year age stratum (30–39 years, 40–49 years, 50–59 years and 60–69 years). Group orientations were held prior to the study at which the study purpose and protocol were explained. Written informed consent was obtained from each subject. Body height was measured to the nearest 0·1 cm with the subject standing without shoes. Body weight in light indoor clothes was measured to the nearest 0·1 kg. BMI was calculated as body weight (kg) divided by the square of body height (m). A total of 121 women and 121 men completed the study protocol. For analyses, a woman whose body weight was mistyped in the database and men aged <30 or >69 years (n 11) were excluded, leaving 120 women and 110 men aged 30–69 years in the analyses.

Diet records

Subjects completed a 4 d weighed DR, comprising four non-consecutive days, four times, once in each season, at intervals of approximately 3 months (DR1 in November and December 2002 (autumn), DR2 in February 2003 (winter), DR3 in May 2003 (spring) and DR4 in August and September 2003 (summer)). Each set of four recording days consisted of one weekend day and three weekdays. Details of the diet record procedure are provided elsewhere[41]. Briefly, during the orientation session, registered dietitians gave the subjects both written and verbal instructions on how to keep the DR, provided recording sheets and a digital scale, and asked the subjects to record and weigh all beverages and foods consumed on each recording day. All collected records were checked by trained registered dietitians in the respective local centre and then again in the study centre.

A total of 1318 beverage and food items appeared in the DR. Energy intake was estimated based on the estimated intakes of all items and the *Standard Tables of Food Composition in Japan*[16]. Caffeine intake was estimated based on the database created in the present study.

In the DR, information on brand names was not required, so we were unable to differentiate brewed beverages made at outlets from those made at home. Caffeine content of some brewed beverages at outlets might have been higher than those made at home[12]. Because information was available on whether beverages were self-prepared or purchased as well as whether they were consumed at food service establishments, we differentiated beverages and foods of various forms as follows. We considered beverages which were reported as self-prepared or consumed at food service establishments to be brewed types. For example, when subjects reported that they self-prepared green tea or drank green tea at a restaurant, we used the food code for brewed green tea. We considered purchased beverages as of the canned or bottled types. For example, when a subject reported that they purchased green tea, we used a food code for a canned or bottled green tea. In addition, for purchased beverages and foods containing other main ingredients (e.g. café au lait, black tea with milk, ice cream, cake, and cookies and snacks), we used food codes created in the present study (no subjects cooked caffeine-containing foods themselves). For example, when a subject reported drinking 100 g of canned black tea with milk (e.g. 90 g black tea and 10 g milk), we used a food code for canned black tea with milk rather than a code for brewed black tea and for milk, but when a subject reported drinking 100 g brewed black tea with milk, we calculated the caffeine intake from 90 g of black tea.

Table 1 Caffeine content of beverages and foods and contribution (%) of each source to caffeine intake* of 230 Japanese subjects†

							Contribution (%)**			
					Caffeine content (mg/100 g)		Women (*n* 120)		Men (*n* 110)	
Source	Item code‡	Step§	Report (*n*)	Sample (*n*)‖	Mean¶	Range of mean	Mean	SD	Mean	SD
Coffee							46·7	29·7	47·1	31·6
1. Black, brewed	16045	1B	3	18	69·9	44·9–92·3	25·8	26·3	21·2	24·8
2. Black, can/bottle	–	1B	4	77	53·0	32·2–92·0	1·8	4·4	4·0	9·4
3. Iced black, can/bottle	–	1B	1	2	91·6	–	0·9	3·8	2·1	10·7
4. Decaffeinated black, brewed	–	1B	1	5	2·6	–	–		–	
5. Instant, dry	16046	1B	4	15	3158·0	2090·0–4780·0	16·5	21·2	14·8	21·4
6. Decaffeinated instant, dry	–	1B	1	5	0·8	–	–		–	
7. Café au lait, can/bottle	–	1A	1	1	44·3	–	0·06	0·401	0·2	1·11
8. Coffee beverage, can/bottle	–	1B	1	8	35·2	–	1·6	5·5	4·8	11·1
Coffee-flavoured beverage							0·2	1·2	0·5	1·8
9. Milk coffee, can/bottle	13007	1B	2	16	16·7	1·5–32·1	0·2	1·1	0·4	1·7
10. Soyamilk coffee, can/bottle	–	1A	1	1	24·0	–	0·02	0·25	0·04	0·38
Black tea							4·3	9·1	3·0	7·0
11. Straight, dry leaf	16043	1B	6	63	3216·0	1680·0–5060·0	0·01	0·12	–	
12. Straight, brewed	16044	1A	4	19	28·1	15·0–49·0	3·6	7·9	2·4	6·0
13. Straight, can/bottle	–	1B	4	33	15·6	11·1–19·2	0·2	1·1	0·2	0·7
14. Milk added, can/bottle	–	1B	2	12	22·1	14·1–38·5	0·4	3·7	0·3	2·3
15. Lemon added, can/bottle	–	1B	1	6	12·5	–	0·05	0·23	0·05	0·35
16. Apple-flavoured, can/bottle	–	1B	1	2	8·9	–	–		–	
17. Herbal tea, can/bottle	–	1B	1	2	5·9	–	–		–	
Japanese and Chinese teas							47·1	30·3	47·4	31·1
18. *Gyokuro*, high-grade green, non-fermented, steamed, dry leaf	16033	1B	3	19	3527·9	3100·0–3750·0	0·2	2·9	0·5	5·5
19. *Gyokuro*, high-grade green, non-fermented, steamed, brewed	16034	1A	1	1	99·0	–	0·6	3·4	0·7	3·4
20. *Gyokuro*, high-grade green, non-fermented, steamed, can/bottle	–	1B	1	2	18·2	–	–		0·01	0·13
21. *Maccha*, finely ground green, non-fermented, steamed, dry powder	16035	1B	5	29	3357·1	2745·0–4170·0	1·5	6·6	0·6	2·6
22. *Maccha*, finely ground green, non-fermented, steamed, can/bottle	–	1A	1	1	7·5	–	–		–	
23. *Sencha*, common grade green, non-fermented, steamed, dry leaf	16036	1B	12	118	2753·8	1745·0–4660·0	0·1	0·5	0·1	0·9
24. *Sencha*, common grade green, non-fermented, steamed, brewed	16037	1B	6	27	52·2	22·5–70·0	31·2	30·0	30·3	30·2
25. *Sencha*, common grade green, non-fermented, steamed, can/bottle	–	1B	3	15	13·2	9·3–20·1	1·1	4·8	1·9	4·1
26. *Kamairicha*, Chinese-type green, non-fermented, pan-fired, dry leaf	–	1B	3	26	3034·6	2590·0–3660·0	–		–	
27. *Kamairicha*, Chinese-type green, non-fermented, pan-fired, brewed	16038	1A	1	1	10·0	–	0·1	0·4	–	
28. *Kamairicha*, Chinese-type green, non-fermented, pan-fired, can/bottle	–	2	–	–	13·2	–	–		–	
29. *Bancha*, coarse leaf green, non-fermented, steamed, dry leaf	–	1B	3	21	1577·1	864·0–2050·0	–		–	
30. *Bancha*, coarse leaf green, non-fermented, steamed, brewed	16039	1A	1	1	10·0	–	3·1	6·6	4·0	9·3
31. *Bancha*, coarse leaf green, non-fermented, steamed, can/bottle	–	2	–	–	13·2	–	–		–	
32. *Hojicha*, a mixture of *sencha* and *bancha*, non-fermented, steamed, dry leaf	–	1B	4	18	1830·8	1673·0–2330·0	–		–	
33. *Hojicha*, a mixture of *sencha* and *bancha*, non-fermented, steamed, brewed	16040	1B	2	4	15·1	13·3–45·0	2·5	9·5	2·3	8·7
34. *Hojicha*, a mixture of *sencha* and *bancha*, non-fermented, steamed, can/bottle	–	1A	1	1	17·4	–	0·1	0·6	0·1	0·5
35. *Genmaicha*, a mixture of brown rice and *sencha* and *bancha*, non-fermented, steamed and roasted, dry leaf	–	2	–	–	1830·8	–	–		–	
36. *Genmaicha*, a mixture of brown rice and *sencha* and *bancha*, non-fermented, steamed and roasted, brewed	16041	1B	1	2	6·0	–	0·6	1·5	0·4	1·6
37. *Genmaicha*, a mixture of brown rice and *sencha* and *bancha*, non-fermented, steamed and roasted, can/bottle	–	1B	1	2	6·3	–	0·02	0·12	0·06	0·27

Table 1 *Continued*

							Contribution (%)**			
					Caffeine content (mg/100 g)		Women (*n* 120)		Men (*n* 110)	
Source	Item code‡	Step§	Report (*n*)	Sample (*n*)‖	Mean¶	Range of mean	Mean	SD	Mean	SD
38. Oolong, Chinese blue, semi-fermented, dry leaf	–	1B	5	23	2583·3	1960·0–4100·0	–		–	
39. Oolong, Chinese blue, semi-fermented, brewed	16042	1B	3	20	25·6	17·4–35·1	5·3	12·8	5·1	13·7
40. Oolong, Chinese blue, semi-fermented, can/bottle	–	1B	4	31	17·4	7·9–26·3	0·6	1·9	1·0	2·7
41. *Mugicha*, roasted barley, brewed	16055	1A	1	1	0	–	0		0	
42. *Mugicha*, roasted barley, can/bottle	–	1B	1	3	0	–	0		0	
43. *Tamaryokucha*, green, non-fermented, steamed, dry leaf	–	1B	3	27	2963·3	2600·0–3310·0	–		–	
44. *Tamaryokucha*, green, non-fermented, steamed, brewed	–	1A	1	1	49·9	–	–		–	
45. *Tamaryokucha*, green, non-fermented, steamed, can/bottle	–	2	–	–	13·2	–	–		–	
46. Blend, mixture of Japanese and Chinese, dry leaf	–	2	–	–	1577·1	–	–		–	
47. Blend, mixture of Japanese and Chinese, brewed	–	2	–	–	10·0	–	–		–	
48. Blend, mixture of Japanese and Chinese, can/bottle	–	1B	1	10	4·9	–	0·01	0·04	0·01	0·04
49. *Pu-erh*, Chinese black, post-fermented, dry leaf	–	1B	3	11	2709·5	2551·0–3550·0	–		–	
50. *Pu-erh*, Chinese black, post-fermented, brewed	–	1B	2	2	28·5	–	–		–	
51. *Pu-erh*, Chinese black, post-fermented, can/bottle	–	2	–	–	17·4	–	–		–	
Cocoa							0·2	0·5	0·1	0·5
52. Pure cocoa, powder	16048	1B	2	5	129·0	10·0–185·0	0·02	0·08	0·02	0·13
53. Milk cocoa, powder	16049	2	–	–	129·0	–	0·2	0·5	0·1	0·5
54. Milk cocoa, brewed	–	1B	1	3	8·8	–	–		–	
55. Milk cocoa, can/bottle	–	1B	2	4	1·8	1·3–3·6	0·001	0·010	0·003	0·030
Soft drinks							0·8	2·3	1·5	2·9
56. Fruit-flavoured soda, can/bottle	16052	2	–	–	10·1	–	0·1	0·3	0·3	0·7
57. Cola, can/bottle	16053	1B	2	7	11·5	10·1–20·7	0·3	1·5	0·4	1·0
58. Soda, can/bottle	16054	1B	2	16	10·1	9·9–12·7	0·4	1·4	0·8	2·1
59. Energy drinks, bottle	–	1B	1	17	72·2	–	0·1	0·8	0·2	1·0
Sweets (mg/100 g)							0·5	0·7	0·3	0·7
60. White chocolate	15115	1B	2	4	10·5	0–42·0	–		–	
61. Milk chocolate	15116	1B	4	52	50·8	6·7–61·0	0·4	0·7	0·3	0·6
62. Chocolate cake	–	1B	2	7	14·2	8·7–15·8	0·007	0·050	0·001	0·013
63. Coffee cake	–	2	–	–	14·2	–	0·0008	0·0092	0·0003	0·0039
64. Chocolate jelly	–	1A	1	1	0	–	0		0	
65. Coffee jelly	15088	1B	2	8	28·9	28·8–29·0	0·06	0·21	0·02	0·16
66. *Maccha* jelly	–	1B	1	5	20·2	–	–		–	
67. Black tea jelly	–	1A	1	1	37·0	–	–		–	
68. Chocolate cookies and biscuits	15114	1B	3	54	16·2	5·1–18·0	0·04	0·13	0·02	0·08
69. *Maccha* cookies and biscuits	–	1B	1	5	21·6	–	–		–	
70. Chocolate ice cream	–	1B	2	10	12·0	1·5–12·0	0·003	0·026	0·005	0·053
71. Coffee ice cream	–	1B	2	3	40·0	28·4–40·0	–		–	
72. *Maccha* ice cream	–	1B	2	9	44·9	29·0–57·7	0·003	0·038	0·014	0·146
73. Coffee candies	–	1B	2	24	54·2	32·9–63·0	–		–	
74. Japanese tea candies	–	1B	2	8	7·3	0·3–19·0	–		–	
75. Black tea candies	–	1B	1	5	7·9	–	–		–	
76. Chewing gum	15118	1B	3	19	104·3	0–843·0	0·005	0·021	0·007	0·048
77. *Maccha*-flavoured *Senbei*, Japanese snack	–	1B	1	10	79·3	–	–		–	
78. *Maccha*-flavoured *Yokan*, Japanese sweets	–	1B	1	10	8·7	–	–		–	

Table 1 *Continued*

Source	Item code‡	Step§	Report (*n*)	Sample (*n*)‖	Caffeine content (mg/100 g) Mean¶	Caffeine content (mg/100 g) Range of mean	Contribution (%)** Women (*n* 120) Mean	Contribution (%)** Women (*n* 120) SD	Contribution (%)** Men (*n* 110) Mean	Contribution (%)** Men (*n* 110) SD
Others							–		–	
79. Chocolate paste	–	1B	1	5	6·6	–	–		–	
80. Chocolate breakfast cereal	–	1A	1	1	5·0	–	–		–	

Can/bottle, canned or polyethylene terephthalate (PET)-bottled.

*Assessed by 16 d weighed diet records.

†Table presents caffeine contents of eighty items (fifty-nine beverages and twenty-one foods).

‡Item codes correspond to the food codes in the *Standard Tables of Food Composition in Japan*[16].

§Database development step: 1A, caffeine value was determined from a single sample of a beverage or food reported in one article; 1B, caffeine value was determined from the mean value of multiple reported samples; 2, caffeine value was determined by assigning analytic values of a similar beverage or food obtained in Step 1.

‖Number of samples analysed by HPLC.

¶Mean values were determined by following Steps 1 and 2.

**In the contribution column (%), – means that the contribution to caffeine intake was zero because no subjects consumed the item and 0 means that contribution to caffeine intake was zero because the item contained no caffeine.

Statistical analyses

All statistical analyses were performed for women and men separately using the SAS statistical software package version 9·1 (SAS Institute Inc., Cary, NC, USA). We categorized the subjects into four age groups (30–39 years, 40–49 years, 50–59 years and 60–69 years). Further, we analysed caffeine intake of the subjects according to BMI (kg/m^2). Because no significant seasonal variation in caffeine intake was observed (data not shown), all analyses were performed using the 16 d mean dietary intake of the subjects.

Results

Mean BMI was 22·3 kg/m^2, ranging from 17·8 kg/m^2 to 31·3 kg/m^2 for women; and 23·8 kg/m^2, ranging from 17·4 kg/m^2 to 30·9 kg/m^2 for men. Mean energy intake was 7732 kJ/d, ranging from 4795 kJ/d to 12552 kJ/d for women; and 10 025 kJ/d, ranging from 5929 kJ/d to 17 334 kJ/d for men. Mean caffeine intake was 256·2 mg/d (4·9 mg/kg body weight per d), ranging from 35·3 mg/d to 821·7 mg/d for women; and 268·3 mg/d (4·1 mg/kg body weight per d), ranging from 35·7 mg/d to 1290·1 mg/d for men.

Table 1 shows the contribution (%) of beverages and foods to caffeine intake in the diet of Japanese subjects. The major contributors to caffeine intake were Japanese and Chinese teas (women: 47·1 %; men: 47·4 %) and coffee (women: 46·7 %; men: 47·1 %).

Table 2 shows caffeine intake by age. The 60–69 years group showed the highest intake of caffeine and caffeine from Japanese and Chinese teas. Caffeine intake from coffee was highest among the 40–49 years group in women and the 30–39 years group in men, while that from black tea was highest among the 30–39 years group in women and 60–69 years group in men.

Table 3 shows caffeine intake by tertile of BMI. For women, subjects in the second tertile (mean BMI: 22·0 kg/m^2) showed the highest intake of caffeine, caffeine from Japanese and Chinese teas and that from coffee, followed by those in the third tertile (mean BMI: 25·6 kg/m^2). In contrast, caffeine from black tea was the highest among those in the third tertile, followed by those in the first tertile (mean BMI: 19·4 kg/m^2). For men, subjects in the third tertile (mean BMI: 26·9 kg/m^2) showed the highest intake of caffeine and caffeine from black tea, followed by those in the first tertile (mean BMI: 20·6 kg/m^2). In contrast, caffeine from Japanese and Chinese teas was the highest among the subjects in the first tertile, followed by those in the third tertile, and that from coffee was the highest among those in the third tertile, followed by those in the second tertile (mean BMI: 23·9 kg/m^2).

Distribution of caffeine intake is shown in Table 4. Intake in 11 % of women and 15 % of men was greater than 400 mg/d, the maximum recommended level suggested to have no negative health effects in review studies[5,6]. Caffeine intake of 56 % of women aged 31–49 years

Table 2 Energy and caffeine intake* of 230 Japanese subjects according to age group

	30–39 years		40–49 years		50–59 years		60–69 years		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Women	(*n* 28)		(*n* 29)		(*n* 32)		(*n* 31)		(*n* 120)	
Energy (kJ/d)	7845	1577	7577	1205	7749	908	7761	1155	7732	1209
Caffeine (mg/d)	212·9	127·7	236·3	91·3	269·8	132·4	299·8	170·8	256·2	132·8
From Japanese and Chinese teas	91·6	74·2	73·8	65·7	119·4	105·9	221·6	157·3	128·3	121·5
From coffee	99·6	96·6	148·7	100·6	140·1	101·5	71·0	46·3	114·9	93·4
From black tea	16·0	31·5	9·2	17·8	8·1	13·6	4·9	8·3	9·4	19·5
Men	(*n* 21)		(*n* 32)		(*n* 28)		(*n* 29)		(*n* 110)	
Energy (kJ/d)	9498	1548	10 498	2180	10 272	1615	9891	1510	10 025	1787
Caffeine (mg/d)	226·5	165·3	257·2	116·9	285·6	241·4	294·3	165·8	268·3	176·2
From Japanese and Chinese teas	58·3	52·5	98·9	82·1	143·5	215·0	215·5	149·1	133·2	151·1
From coffee	151·7	138·8	146·9	117·3	137·6	110·7	65·1	65·2	123·9	113·3
From black tea	7·6	12·7	5·1	11·4	2·1	3·6	10·8	23·3	6·3	14·8

*Assessed by 16 d weighed diet records.

Table 3 Caffeine intake* of 230 Japanese subjects according to tertile of BMI

	T1		T2		T3	
	Mean	SD	Mean	SD	Mean	SD
Women	(*n* 39)		(*n* 41)		(*n* 40)	
BMI (kg/m^2)	19·4	0·8	22·0	0·8	25·6	1·9
Range (kg/m^2)	17·8–20·5		20·7–23·3		23·5–31·3	
Caffeine (mg/d)	229·3	113·2	290·9	152·8	246·8	123·7
From Japanese and Chinese teas	107·9	85·1	127·1	92·9	109·0	102·4
From coffee	107·8	85·4	153·4	158·8	122·5	104·6
From black tea	10·0	15·6	6·7	14·7	11·4	26·3
Men	(*n* 37)		(*n* 36)		(*n* 37)	
BMI (kg/m^2)	20·6	1·5	23·9	0·7	26·9	1·4
Range (kg/m^2)	17·4–22·6		22·7–25·0		25·2–30·9	
Caffeine (mg/d)	266·6	152·1	255·9	211·3	282·2	164·6
From Japanese and Chinese teas	140·2	116·6	104·4	86·9	126·5	131·5
From coffee	114·9	99·7	142·5	194·1	142·6	148·5
From black tea	6·1	12·6	5·4	17·3	7·4	14·6

*Assessed by 16 d weighed diet records.

Table 4 Distribution of caffeine intake* among 230 Japanese subjects according to age group

	30–39 years		40–49 years		50–59 years		60–69 years		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Women	(*n* 28)		(*n* 29)		(*n* 32)		(*n* 31)		(*n* 120)	
35–199 mg/d	15	53·6	10	34·5	9	28·1	8	25·8	42	35·0
200–399 mg/d	11	39·3	18	62·1	18	56·3	18	58·1	65	54·1
400–822 mg/d	2	7·1	1	3·4	5	15·6	5	16·1	13	10·8
Men	(*n* 21)		(*n* 32)		(*n* 28)		(*n* 29)		(*n* 110)	
35–199 mg/d	13	61·9	15	46·9	11	39·3	8	27·6	47	42·7
200–399 mg/d	6	28·6	13	40·6	12	42·9	15	51·7	46	41·8
400–822 mg/d	2	9·5	4	12·5	5	17·8	6	20·7	17	15·4

*Assessed by 16 d weighed diet records.

(around reproductive age) was more than 200 mg/d, the maximum recommended level for women of reproductive age issued by the UK Food Standards Agency(11).

Discussion

To our knowledge, this is the first study to estimate caffeine intake in an Asian population using a detailed diet assessment method (i.e. DR). Although several previous studies in Western countries estimated intake in individuals using detailed diet assessment methods(1,12–15), some(1,12,15) of these estimated intake from a few beverages only (i.e. coffee, black tea and soft drinks) and/or chocolate. In the present study, we developed a comprehensive caffeine database which considered beverages in various forms and foods. We found that mean caffeine intake among the Japanese subjects in the present study was 256·2 mg/d (4·9 mg/kg body weight per d) for women and 268·3 mg/d (4·1 mg/kg body weight per d) for men. The major contributors to intake were Japanese and Chinese teas and coffee.

Mean caffeine intake in several previous Western studies which assessed intake using detailed diet assessment methods (e.g. 24 h recall and diet record) ranged from 173·9 to 490·0 mg/d (1·9 to 7·0 mg/kg body weight per d)[1,12–15]. Thus, caffeine intake in this Japanese population was comparable to the estimated intake in Western populations. Some discrepant estimates among studies may be attributable to differences in populations and dietary habits. Another reason may be that different databases comprising different analytical values were used. Moreover, the number of items (beverages only or beverages and foods) and sources of caffeine intake in the databases varied among studies. Coffee contributed the largest part[1,13–15] of intake in most of the previous studies in Western populations (e.g. 71 % to 86 %)[13–15], with the exception of UK women, whose largest source was black tea (43 %), followed by coffee (17 %) and confections (17 %)[12]. Among a US population, soft drinks were the second largest source (16 %) after coffee (71 %), while confections contributed only a small part (1·7 %)[14]. In contrast, Japanese and Chinese teas and coffee were the largest sources of intake among subjects in the present study, and black tea and soft drinks contributed only a small part (women: 4·3 % and 0·8 %; men: 3·0 % and 1·5 %, respectively). Regarding the form of beverages, canned and PET-bottled beverages contributed 8 % of caffeine intake in women and 17 % in men, suggesting that future studies of associations between caffeine intake and health status in Japanese populations may be better to differentiate the various forms of beverages.

In some previous Western studies with detailed diet assessments which examined caffeine intake and sources according to age group, results differed among populations[1,14,15]. In a US population aged >20 years, the 50–64 years group showed the highest caffeine intake, whereas coffee and black tea intake peaked in the 25–34 years group[1]. A second US population aged >18 years showed the highest caffeine and black tea intake in the 35–54 years group, but highest coffee intake in the 35–54 years group in women and the 55–64 years group in men[14]. In a Danish population aged >20 years, caffeine and coffee intake was highest in the 35–49 years group whereas black tea intake peaked in the 25–34 years group[1]; while in an Icelandic population aged 15–80 years, coffee intake was highest in the 40–59 years group, while black tea intake peaked in the 60–80 years group[15]. In our study, caffeine intake was highest in the 60–69 years group, and thus different to these Western populations, whereas coffee intake was higher among the younger age groups and thus consistent with them. The high caffeine intake of older age groups may be explained by their high intake of Japanese and Chinese teas. Japanese and Chinese teas are traditionally consumed both at meals and with snacks in Japan, and such dietary habits may be more pronounced among older populations.

According to tertile of BMI, caffeine intake of women was the highest in the second tertile and that of men was the highest in the third tertile (Table 3). Data of caffeine intake according to BMI are not available from the previous studies with detailed diet assessments. To our knowledge, the only available observational evidence is a cohort study in American adults, which assessed caffeine intake of the subjects using a semi-quantitative FFQ[8]. The study found an increase in caffeine intake was associated with a smaller weight gain. Since moderate caffeine intake has been suggested to be effective to prevent type 2 diabetes[6] and weight gain is a major factor of type 2 diabetes, more studies examining the association of caffeine intake with obesity measures are needed.

Several limitations of the present study should be mentioned. Although our caffeine composition database considered various types and forms of beverages and foods, these do not represent the total number of beverage and food products on the market. Further, analytic caffeine values were not available for all types of beverages and foods. However, the contribution to intake of items whose values were assigned from similar items was 0·3 % in women and 0·4 % in men, suggesting that the influence of such values on our results was likely negligible. Also, plant varieties, fermentation methods of tea leaves, analytical methods and preparation (brewing) methods for beverages, such as the length of infusion, cup size and temperature, might also have produced errors[1]. Moreover, since the DR was not designed solely for the estimation of caffeine intake and did not enquire about brand names, we were unable to differentiate brewed coffee made at home from that made at coffee outlets. Although we considered any kind of tea and coffee served at a food service establishment as of the brewed type, some establishments might have offered canned or PET-bottled beverages. Further, although we asked the subjects to report all beverages and foods in the DR in detail, some subjects may not have differentiated similar items, such as canned black coffee and canned coffee beverages. In addition, although decaffeinated coffee did not appear in the DR and is not commonly consumed in Japan, we cannot exclude the possibility that some subjects had decaffeinated coffee. Nevertheless, we ensured that we obtained all relevant data from sources with suitably clear and comprehensive assessment methodologies, and then carefully conducted matching processes to maximize database reliability. The use of DR allows detailed assessment of the dietary intake of individuals; however, since energy intake (a surrogate measure of overall dietary intake) in older age groups did not tend to be lower than that in younger age groups, our results for caffeine intake by age group should be interpreted with caution. Given that total energy expenditure should be lower in older than younger age groups[42] and that under-reporting is a common problem even in self-reported weighed DR[43], the present study may be biased by under-reporting among younger age groups, which would in turn mean the underestimation of caffeine intake among younger age groups. Nevertheless, we found that caffeine intake from Japanese and Chinese teas in the 60–69 years age group was more than double that in the 30–39 years group, suggesting that the high caffeine intake from Japanese and Chinese teas among the older age groups cannot be explained by under-reporting by younger age groups alone. Finally, our subjects were not a representative sample of the general Japanese population but volunteers, who may have been more nutritionally conscious than others who did not participate. Our results may thus not be generalizable to the entire Japanese population.

Although mean caffeine intake in our present Japanese adults was within the maximum level recommended in reviews to have no negative health effects (400 mg/d)[5,6], 11 % of women and 15 % of men consumed more than 400 mg/d. Following the UK Food Standards Agency's recent renewal of advice to women of reproductive age to limit intake below 200 mg/d, caffeine intake in this population is now also of concern. In our subjects, 56 % of women aged 31–49 years (around reproductive age) consumed more than 200 mg/d, but given the possibility of underestimation by younger age groups, the proportion of young women with an intake above 200 mg/d and of all subjects with an intake above 400 mg/d may be higher than our estimates. Currently, no recommended level is provided in Japan. Further research targeting women of reproductive age is warranted.

In conclusion, caffeine intake in this Japanese population was comparable to the estimated values reported in Western populations. Also, the caffeine database developed in the present study may be a valuable tool in future studies of the association between caffeine intake and health status among Japanese populations.

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References

1. Barone JJ & Roberts HR (1996) Caffeine consumption. *Food Chem Toxicol* **34**, 119–129.
2. Graham DM (1978) Caffeine – its identity, dietary sources, intake and biological effects. *Nutr Rev* **36**, 97–102.
3. McCusker RR, Goldberger BA & Cone EJ (2006) Caffeine content of energy drinks, carbonated sodas, and other beverages. *J Anal Toxicol* **30**, 112–114.
4. Carrillo JA & Benitez J (2000) Clinically significant pharmacokinetic interactions between dietary caffeine and medications. *Clin Pharmacokinet* **39**, 127–153.
5. Nawrot P, Jordan S, Eastwood J *et al.* (2003) Effects of caffeine on human health. *Food Addit Contam* **20**, 1–30.
6. Higdon JV & Frei B (2006) Coffee and health: a review of recent human research. *Crit Rev Food Sci Nutr* **46**, 101–123.
7. Cornelis MC & El-Sohemy A (2007) Coffee, caffeine, and coronary heart disease. *Curr Opin Clin Nutr Metab Care* **10**, 745–751.
8. Lopez-Garcia E, van Dam RM, Rajpathak S *et al.* (2006) Changes in caffeine intake and long-term weight change in men and women. *Am J Clin Nutr* **83**, 674–680.
9. The EU Scientific Committee for Food (1999) Opinion on Caffeine, Taurine and D-Glucurono-γ-Lactone as constituents of so-called 'energy' drinks (expressed on 21 January 1999). http://ec.europa.eu/food/fs/sc/scf/out22_en.html (accessed December 2008).
10. Health Canada (2003) Caffeine and your health. http://www.hc-sc.gc.ca/fn-an/securit/facts-faits/caffeine-eng.php (accessed December 2008).
11. Food Standards Agency (2008) Food Standards Agency publishes new caffeine advice for pregnant women. http://www.food.gov.uk/news/pressreleases/2008/nov/caffeineadvice (accessed December 2008).
12. Derbyshire E & Abdula S (2008) Habitual caffeine intake in women of reproductive age. *J Hum Nutr Diet* **21**, 159–164.
13. Cotton PA, Subar AF, Friday JE *et al.* (2004) Dietary sources of nutrients among US adults, 1994 to 1996. *J Am Diet Assoc* **104**, 921–930.
14. Frary CD, Johnson RK & Wang MQ (2005) Food sources and intakes of caffeine in the diets of persons in the United States. *J Am Diet Assoc* **105**, 110–113.
15. The Environment and Food Agency of Iceland (2004) Caffeine consumption in Iceland in 2002. http://english.ust.is/media/ljosmyndir/matvaeli/caffeine_consumption.pdf (accessed December 2008).
16. Science and Technology Agency (2005) *Standard Tables of Food Composition in Japan*, 5th ed. Tokyo: Printing Bureau of the Ministry of Finance (in Japanese).
17. Japan Soft Drink Association (2008) *Data of Soft Drink-related Statistics.* Tokyo: Japan Soft Drink Association (in Japanese).
18. Kizu J, Kimoto K, Arakawa Y *et al.* (1998) Caffeine content of canned beverages and sustained high plasma concentration of caffeine after intake. *Chromatography* **19**, 217–224 (in Japanese).
19. Maekawa H, Yamazaki Y & Yagasaki K (1993) Extraction of theobromine and caffeine in the cocoa powder by DMSO (Report I). *Rep Central Customs Lab* **32**, 93–96 (in Japanese).
20. Terada H, Suzuki A, Tanaka H *et al.* (1992) Determination of catechins and methyxanthines in foodstuffs by semi-micro high performance liquid chromatography. *J Food Hyg Soc Jpn (Shokuhin Eiseigaku Zasshi)* **33**, 347–354 (in Japanese).
21. Oyagi M (1988) Analysis of tea: measurement methods for caffeine contents in tea by high performance liquid chromatography. *Den-en chofu Univ J* **21**, 216–243 (in Japanese).

22. Ueki T, Honda H & Sakurai S (1986) *Analysis of Chlorogenic Acids and Caffeine in Coffee-containing Beverages by High Performance Liquid Chromatography: Reports of Surveys and Research*. Saitama: Food and Agricultural Materials Inspection Center; available at http://www.famic.go.jp/technical_information/investigation_research_report/pdf/1003.pdf
23. Goto T, Nagashima H, Yoshida Y *et al.* (1996) Contents of individual tea catechins and caffeine in Japanese green tea. *Tea Res J* **83**, 21–28 (in Japanese).
24. Goto T, Horie H, Ozeki Y *et al.* (1994) Chemical composition of Japanese green teas on market. *Tea Res J* **80**, 23–28 (in Japanese).
25. Ikegaya K (1985) Determination of caffeine in tea by high performance liquid chromatography. *Nippon Shokuhin Kogyo Gakkaishi* **32**, 61–66 (in Japanese).
26. Kishi H (2008) Measurements of contents of caffeine and theobromine in chocolate products and chewing gums. *Bull Kanagawa Prefectural Inst Public Health* **38**, 23–25 (in Japanese).
27. Kishi H, Tsuchiya H & Hirayama K (2005) Determination of catachins, caffeine, and theanine in Chinese tea bought by internet. *Bull Kanagawa Prefectural Inst Public Health* **35**, 30–32 (in Japanese).
28. Kunugi A, Aoki T & Kunigi S (1988) Determination of caffeine in coffee, black tea and green tea by high performance liquid chromatography. *J Food Hyg Soc Jpn (Shokuhin Eiseigaku Zasshi)* **29**, 136–140 (in Japanese).
29. Moriyasu T, Saito K, Nakazato M *et al.* (1996) Survey of caffeine, theobromine and theophylline in foods. *J Food Hyg Soc Jpn (Shokuhin Eiseigaku Zasshi)* **37**, 59–63 (in Japanese).
30. Fukuhara K, Matsuki Y & Nanbara T (1985) Simultaneous determination of theobromine, theophylline, and caffeine in foods by high performance liquid chromatography. *J Food Hyg Soc Jpn (Shokuhin Eiseigaku Zasshi)* **26**, 208–212 (in Japanese).
31. Shimizu H & Watanabe Y (1992) Determination of caffeine in tea leaf infusion by high performance liquid chromatography. *Gifu City Women's Coll J* **42**, 33–38 (in Japanese).
32. Hino C, Miura T, Umeda H *et al.* (2005) Differentiation of tea categories by the composition of tea polyphenols and caffeine. *Rep Central Customs Lab* **24**, 23–32 (in Japanese).
33. Kuwano K & Mitamura T (1986) HPLC determination of caffeine in marketed green tea. *Nippon Nogeikagaku Kaishi* **60**, 115–117 (in Japanese).
34. Nishizawa M, Chonan T, Sekijo I *et al.* (1982) Quantitative determination of caffeine, theobromine and theophylline in tea, coffee and cocoa by high performance liquid chromatography. *Bull Hokkaido Prefectural Inst Public Health* **32**, 7–11 (in Japanese).
35. Chonan T, Nishizawa M & Sekijo I (1983) Caffeine, theobromine and theophylline contents of confectioneries and beverages. *Bull Hokkaido Prefectural Inst Public Health* **33**, 84–86 (in Japanese).
36. Terada S, Maeda Y, Masui T *et al.* (1987) Comparison of caffeine and catechin components in infusion of various tea (green, oolong and black tea) and tea drinks. *Nippon Shokuhin Kogyo Gakkaishi* **34**, 20–27 (in Japanese).
37. Terada H & Sakabe Y (1984) High-performance liquid chromatographic determination of theobromine, theophylline and caffeine in food products. *J Chromatogr* **291**, 453–459 (in Japanese).
38. Konno S, Kanbara Y & Bunbayashi R (2000) Caffeine analysis of tea. *Kinran Coll Res J* **31**, 131–134 (in Japanese).
39. Sumitani H, Suekane S, Nakatani A *et al.* (1994) Quantitative determination of caffeine in commercially canned black tea drink with milk. *Res Rep Toyo Food Lab* **20**, 149–154 (in Japanese).
40. Gilbert RM (1984) *The Methylxanthine Beverages and Foods: Chemistry, Consumption, and Health Effects*, pp. 185–213. New York: Alan R. Liss, Inc.
41. Murakami K, Sasaki S, Takahashi Y *et al.* (2008) Reproducibility and relative validity of dietary glycaemic index and load assessed with a self-administered diet-history questionnaire in Japanese adults. *Br J Nutr* **99**, 639–643.
42. Black AE, Coward WA, Cole TJ *et al.* (1996) Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. *Eur J Clin Nutr* **50**, 72–92.
43. Trabulsi J & Schoeller DA (2001) Evaluation of dietary assessment instruments against doubly labeled water, a biomarker of habitual energy intake. *Am J Physiol Endocrinol Metab* **281**, E891–E899.