Table 2 Independent association of monetary cost of dietary energy with metabolic risk factors (*n* 1136)*: subset of participants in the Japan Dietetic Students' Study for Nutrition and Biomarkers, 2006 and 2007

	Analysis treating monetary cost of dietary energy as a categorical variable											Analysis treating monetary cost of dietary energy as a continuous variable		
	Quintile of monetary cost of dietary energy													
	1 (*n* 227)		2 (*n* 227)		3 (*n* 228)		4 (*n* 227)		5 (*n* 227)					
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	*P* for trend†	Regression coefficient	95 % CI‡	*P*
Monetary cost of dietary energy (Japanese yen/4184 kJ)§	349	255, 382	399	382, 422	440	422, 458	478	458, 505	544	505, 781				
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI				
BMI (kg/m^2)														
Model 1‖	21·9	21·5, 22·3	21·3	20·9, 21·7	21·4	21·0, 21·8	21·2	20·8, 21·6	21·0	20·6, 21·4	0·0024	−0·38	−0·60, −0·16	0·0006
Model 2¶	21·6	21·2, 22·0	21·2	20·8, 21·6	21·4	21·0, 21·8	21·3	20·9, 21·7	21·3	20·9, 21·7	0·46	−0·16	−0·48, 0·17	0·34
Model 3**	21·8	21·4, 22·2	21·2	20·8, 21·6	21·4	21·0, 21·8	21·2	20·8, 21·6	21·1	20·7, 21·5	0·0199	−0·33	−0·57, −0·09	0·0067
Waist circumference (cm)														
Model 1	74·9	73·9, 75·9	72·6	71·6, 73·6	73·1	72·3, 73·9	72·5	71·5, 73·5	71·4	70·4, 72·4	<0·0001	−1·46	−2·01, −0·90	<0·0001
Model 4††	73·9	73·3, 74·5	72·7	72·1, 73·3	73·0	72·4, 73·6	72·8	72·2, 73·4	72·1	71·5, 72·7	0·0003	−0·71	−1·07, −0·36	0·0001
Model 5‡‡	73·8	73·2, 74·4	72·7	72·1, 73·3	73·0	72·4, 73·6	72·8	72·2, 73·4	72·3	71·5, 73·1	0·0322	−0·64	−1·16, −0·11	0·0174
Model 6§§	73·6	73·0, 74·2	72·6	72·0, 73·2	73·0	72·4, 73·5	72·9	72·3, 73·5	72·4	71·8, 73·0	0·0391	−0·45	−0·84, −0·06	0·0247
Systolic blood pressure (mmHg)														
Model 1	107·0	105·6, 108·4	106·7	105·3, 108·1	106·3	104·9, 107·7	106·9	105·5, 108·3	105·0	103·6, 106·4	0·08	−0·93	−1·74, −0·11	0·025
Model 4	106·3	104·9, 107·7	106·8	105·6, 108·0	106·3	105·1, 107·5	107·1	105·9, 108·3	105·4	104·2, 106·6	0·39	−0·50	−1·28, 0·27	0·20
Diastolic blood pressure (mmHg)														
Model 1	69·9	68·9, 70·9	69·0	68·0, 70·0	69·1	68·1, 70·1	69·6	68·6, 70·6	69·1	68·1, 70·1	0·52	−0·31	−0·95, 0·34	0·35
Model 4	69·5	68·5, 70·5	69·1	68·1, 70·1	69·1	68·1, 70·1	69·7	68·7, 70·7	69·3	68·3, 70·3	0·87	−0·02	−0·64, 0·61	0·96
Total cholesterol (mg/dl)														
Model 1	188·5	184·2, 192·8	187·1	183·0, 191·2	186·3	182·2, 190·4	190·8	186·7, 194·9	191·6	187·3, 195·9	0·15	1·46	−1·16, 4·09	0·27
Model 4	188·2	183·9, 192·5	187·1	183·0, 191·2	186·3	182·2, 190·4	190·9	186·8, 195·0	191·8	187·5, 196·1	0·10	1·77	−0·86, 4·40	0·19
HDL cholesterol (mg/dl)														
Model 1	71·1	69·3, 72·9	70·0	68·2, 71·8	70·5	68·9, 72·1	69·7	67·9, 71·5	71·4	69·6, 73·2	0·81	−0·01	−1·06, 1·04	0·98
Model 4	71·4	69·6, 73·2	70·0	68·4, 71·6	70·5	68·9, 72·1	69·6	68·0, 71·2	71·1	69·3, 72·9	0·83	−0·29	−1·33, 0·75	0·59
LDL cholesterol (mg/dl)														
Model 1	106·9	103·2, 110·6	105·5	102·0, 109·0	104·5	101·0, 108·0	110·1	106·6, 113·6	107·9	104·2, 111·6	0·32	0·83	−1·42, 3·07	0·47
Model 4	106·2	102·5, 109·9	105·5	102·0, 109·0	104·5	101·0, 108·0	110·3	106·8, 113·8	108·4	104·7, 112·1	0·15	1·40	−0·83, 3·64	0·22
Fasting TAG (mg/dl)														
Model 1	60·0	56·1, 63·9	65·4	61·7, 69·1	59·0	55·2, 62·7	61·4	57·5, 65·3	59·8	55·9, 63·7	0·56	−1·13	−3·53, 1·27	0·36
Model 4	59·3	55·4, 63·2	65·3	61·6, 69·0	59·0	55·3, 62·7	61·6	57·9, 65·3	60·1	56·2, 64·0	0·82	−0·65	−3·04, 1·74	0·60
Fasting glucose (mg/dl)														
Model 1	84·2	83·4, 85·0	84·1	83·3, 84·9	83·9	83·1, 84·7	84·9	84·1, 85·7	83·1	82·3, 83·9	0·24	−0·57	−1·10, −0·04	0·034
Model 4	84·2	83·4, 85·0	84·1	83·3, 84·9	83·9	83·1, 84·7	84·9	84·1, 85·7	83·2	82·4, 84·0	0·31	−0·53	−1·06, 0·00	0·051
Glycated haemoglobin (%)														
Model 1	4·85	4·81, 4·89	4·88	4·84, 4·92	4·88	4·84, 4·92	4·86	4·82, 4·90	4·86	4·82, 4·90	0·94	−0·52	−1·05, 0·02	0·06
Model 4	4·85	4·81, 4·89	4·88	4·84, 4·92	4·88	4·84, 4·92	4·86	4·82, 4·90	4·86	4·82, 4·90	0·88	0·00	−0·02, 0·02	0·97

**n* 1121 for cholesterol (total, HDL and LDL) and glycated haemoglobin (224 in the first, second, fourth and fifth and 225 in the third quintiles); *n* 1088 for fasting TAG (217 in the first and fifth and 218 in the second, third and fourth quintiles); and *n* 1089 for fasting glucose (217 in the first and 218 in the second, third, fourth and fifth quintiles). For monetary cost of dietary energy, median value in each quintile is almost the same (within <3 Japanese yen/4184 kJ difference) in all analyses.

†A linear trend test was used with the median value in each quintile as a continuous variable in linear regression analysis.

‡Regression coefficient (95 % CI) of variation of metabolic risk factors by an increase in monetary cost of dietary energy (100 Japanese yen/4184 kJ).

§1 Japanese yen = 0·006 € = 0·008 $US in June 2007.

‖Adjusted for residential block (north (Kanto, Hokkaido and Tohoku), central (Tokai, Hokuriku and Kinki), south (Kyushu and Chugoku)), size of residential area (city with population ≥1 million, city with population with <1 million, town or village), living status (living with family, living alone, others), survey year (2006 or 2007), current smoking (yes or no), currently trying to lose weight (yes or no), rate of eating (slow, medium, fast) and physical activity (total metabolic equivalents-hours per day, continuous).

¶Adjusted for variables used in model 1 and intakes (continuous) of protein (% of energy), fat (% of energy) and dietary fibre (g/4184 kJ).

**Adjusted for variables used in model 1 and dietary energy density (kJ/g, continuous).

††Adjusted for variables used in model 1 and BMI (kg/m^2, continuous).

‡‡Adjusted for variables used in model 4 and intakes (continuous) of protein (% of energy), fat (% of energy) and dietary fibre (g/4184 kJ).

§§Adjusted for variables used in model 4 and dietary energy density (kJ/g, continuous).

other metabolic risk factors examined, except for inverse associations between monetary cost of dietary energy treated as a continuous variable and systolic blood pressure and fasting glucose in the analysis with adjustment for potential confounding factors except for BMI (model 1).

Discussion

We found that monetary cost of dietary energy was independently negatively associated with BMI and waist circumference, but not with other metabolic risk factors, in a group of young Japanese women. To our knowledge, this is the first study to examine the association of monetary diet cost with not only BMI but also other metabolic risk factors. The present findings may imply that public health interventions aimed at decreasing the energy cost of healthy diets could have a potential to improve population health.

Consistent with previous Spanish(3) and Japanese(4) studies, we found that the monetary cost of dietary energy was negatively associated with BMI in a group of lean and young Japanese women. Additionally, we also found for the first time a negative relationship with waist circumference. These negative relationships were not generally explained by dietary composition or energy density (possible causal pathways), or by other lifestyle factors. The reason for the independent association of monetary cost of dietary energy with BMI and waist circumference is currently unknown. However, as having or using money is unlikely directly related to obesity, monetary cost of dietary energy might be a surrogate for factors associated with obesity such as socio-economic level or income (of families), which may be associated with obesity through several potential mechanisms including psychological distress, neighbourhood characteristics and access to health care(19,20).

In this lean and young population, monetary cost of dietary energy was not associated with other metabolic risk factors, independently of potential confounding factors. As this is the first study on this topic, comparison of our results with others cannot readily be made. Monetary diet cost might not have an influence on metabolic risk factors except for BMI and waist circumference in lean and young and hence probably healthy populations.

Several limitations of the present study warrant mention. First, our subjects were selected female dietetic students. They were therefore more likely than the general population to have a healthy diet, or to fulfil the recommendations, or to declare fulfilling them. Our subjects were also young. They were therefore more likely to be healthy, with a low prevalence of abnormal biological and anthropometric values. Both of these important selection biases are likely to have induced an underestimation of the studied association between monetary cost of dietary energy and metabolic risk factors. Nevertheless, as an association was found even in this young and probably healthy population (at least for BMI and waist circumference), one can expect that a stronger association would be found in the general population.

Second, in the absence of actual food expenditure data, food prices were derived from the National Retail Price Survey and websites of nationally distributed supermarket and fast-food restaurant chains. As this procedure gives only an approximation of actual diet costs, the results of the present study should be interpreted with caution. We note, however, that a similar methodology has been used in all previous observational studies(1–4,10–12,17).

Third, although we used a validated DHQ, the misreporting of dietary intake, particularly by overweight subjects, is a serious problem associated with self-report dietary assessment methods(21). Nevertheless, at least for protein, K and Na intake, BMI-dependent misreporting has been shown to be cancelled by energy adjustment(21). To minimize the influence of dietary misreporting as much as possible, we used energy-adjusted values of monetary diet cost (monetary cost of dietary energy)(4).

Fourth, although adjustments were attempted to compensate for a variety of potential confounding variables, residual confounding could not be ruled out. In particular, physical activity was assessed relatively roughly from only five activities, which may not have been sufficient. Finally, the cross-sectional nature of the study does not permit the assessment of causality owing to the uncertain temporality of the association.

In conclusion, monetary cost of dietary energy was independently negatively associated with BMI and waist circumference, but not with other metabolic risk factors, in a group of young Japanese women. Because the relationship between monetary diet cost and health status is an important topic for public health nutrition, our observation in a selected population should be confirmed using more precise evaluation of diet costs or actual food expenditures in a more representative sample of the Japanese population.

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References

1. Cade J, Upmeier H, Calvert C & Greenwood D (1999) Costs of a healthy diet: analysis from the UK Women's Cohort Study. *Public Health Nutr* **2**, 505–512.
2. Andrieu E, Darmon N & Drewnowski A (2006) Low-cost diets: more energy, fewer nutrients. *Eur J Clin Nutr* **60**, 434–436.
3. Schroder H, Marrugat J & Covas MI (2006) High monetary costs of dietary patterns associated with lower body mass index: a population-based study. *Int J Obes (Lond)* **30**, 1574–1579.
4. Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y & Itabashi M (2007) Monetary costs of dietary energy reported by young Japanese women: association with food and nutrient intake and body mass index. *Public Health Nutr* **10**, 1430–1439.
5. Sasaki S, Yanagibori R & Amano K (1998) Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol* **8**, 203–215.
6. Sasaki S, Yanagibori R & Amano K (1998) Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-hour urinary excretion. *Jpn Circ J* **62**, 431–435.
7. Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y & Toyooka E (2000) Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. *J Nutr Sci Vitaminol (Tokyo)* **46**, 285–296.
8. Science and Technology Agency (2005) *Standard Tables of Food Composition in Japan*, 5th ed. Tokyo: Printing Bureau of the Ministry of Finance.
9. Murakami K, Sasaki S, Takahashi Y & Uenishi K; the Japan Dietetic Students' Study for Nutrition and Biomarkers Group (2007) Dietary energy density is associated with body mass index and waist circumference, but not with other metabolic risk factors, in free-living young Japanese women. *Nutrition* **23**, 798–806.
10. Maillot M, Darmon N, Vieux F & Drewnowski A (2007) Low energy density and high nutritional quality are each associated with higher diet costs in French adults. *Am J Clin Nutr* **86**, 690–696.
11. Darmon N, Briend A & Drewnowski A (2004) Energy-dense diets are associated with lower diet costs: a community study of French adults. *Public Health Nutr* **7**, 21–27.
12. Drewnowski A, Darmon N & Briend A (2004) Replacing fats and sweets with vegetables and fruits – a question of cost. *Am J Public Health* **94**, 1555–1559.
13. Price Statistics Office, Statistics Bureau (2004) National Retail Price Survey in Japan. http://www.stat.go.jp/data/kouri/index.htm (accessed June 2007).
14. Trichopoulou A, Gnardellis C, Benetou V, Lagiou P, Bamia C & Trichopoulos D (2002) Lipid, protein and carbohydrate intake in relation to body mass index. *Eur J Clin Nutr* **56**, 37–43.
15. Riccardi G, Giacco R & Rivellese AA (2004) Dietary fat, insulin sensitivity and the metabolic syndrome. *Clin Nutr* **23**, 447–456.
16. Bo S, Durazzo M, Guidi S, Carello M, Sacerdote C, Silli B, Rosato R, Cassader M, Gentile L & Pagano G (2006) Dietary magnesium and fiber intakes and inflammatory and metabolic indicators in middle-aged subjects from a population-based cohort. *Am J Clin Nutr* **84**, 1062–1069.
17. Drewnowski A, Monsivais P, Maillot M & Darmon N (2007) Low-energy-density diets are associated with higher diet quality and higher diet costs in French adults. *J Am Diet Assoc* **107**, 1028–1032.
18. Mendoza JA, Drewnowski A & Christakis DA (2007) Dietary energy density is associated with obesity and the metabolic syndrome in US adults. *Diabetes Care* **30**, 974–979.
19. Dallongeville J, Cottel D, Ferrieres J, Arveiler D, Bingham A, Ruidavets JB, Haas B, Ducimetière P & Amouyel P (2005) Household income is associated with the risk of metabolic syndrome in a sex-specific manner. *Diabetes Care* **28**, 409–415.
20. Loucks EB, Rehkopf DH, Thurston RC & Kawachi I (2007) Socioeconomic disparities in metabolic syndrome differ by gender: evidence from NHANES III. *Ann Epidemiol* **17**, 19–26.
21. Murakami K, Sasaki S, Takahashi Y *et al.* (2008) Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women. *Eur J Clin Nutr* **62**, 111–118.

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Applied nutritional investigation

Neighborhood socioeconomic status in relation to dietary intake and body mass index in female Japanese dietetic students

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Abstract

Objective: An increasing number of studies conducted in Western countries have shown that living in a socioeconomically disadvantaged neighborhood is associated with unfavorable dietary intake patterns and an unfavorable health status. However, information on such neighborhood socioeconomic differences in diet and health among different cultural settings, including Japan, is absolutely lacking. This cross-sectional study examined the association of neighborhood socioeconomic status (SES) with dietary intake and body mass index (BMI) in a group of young Japanese women.

Methods: Subjects were 3892 female Japanese dietetic students 18–20 y of age from 53 institutions, residing in 1033 municipalities in 47 prefectures in Japan. Neighborhood SES index was defined by seven municipal-level variables, namely unemployment, household overcrowding, poverty, education, income, home ownership, and vulnerable groups, with an increasing index signifying increasing neighborhood socioeconomic disadvantage. Dietary intake was estimated using a validated, comprehensive self-administered diet history questionnaire. BMI was computed from self-reported body weight and height.

Results: Neighborhood SES index was not materially associated with most of the dietary variables. However, neighborhood SES index was positively associated with BMI, with significance (*P* for trend = 0.020). This significant association remained after adjustment for potential confounding or mediating factors including household SES, dietary, other lifestyle, and geographic factors (*P* for trend = 0.037).

Conclusion: Although no material association was seen between neighborhood SES and dietary intake, increasing neighborhood socioeconomic disadvantage was independently associated with increasing BMI in a group of young Japanese women. © 2009 Elsevier Inc. All rights reserved.

Keywords: Neighborhood socioeconomic status; Diet; Body mass index; Young women; Japan; Epidemiology

Introduction

Because living conditions are shaped by characteristics of the residential environment, neighborhood characteristics may have some impact on lifestyle factors such as dietary habits and, hence, on health status such as obesity, beyond any effect of the characteristics of the individual such as smoking status [1] and individual socioeconomic status (SES) [2]. In fact, an increasing number of studies has shown that living in a socioeconomically disadvantaged neighborhood is associated with unfavorable dietary intake patterns including lower fruit and vegetable consumption [3–6] and an unfavorable health status, including obesity [7–10].

To our knowledge, however, all studies on this topic have been conducted in Western countries, with none reported in Asian countries, including Japan. Given the unclear or even inverse association between individual SES and health outcomes observed in several Japanese populations [11–13]

[†] Other members of the Freshmen in Dietetic Courses Study II Group have been listed previously (Eur J Clin Nutr 2007;61:616–22).

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vis-à-vis the consistent positive associations of individual and neighborhood SES with diet and health in Western populations [3–10,14–18], the association of neighborhood SES with dietary intake and health outcomes may differ between Western countries and Japan.

Health inequalities in relation to neighborhood SES are of particular interest in public health. Understanding the associations between neighborhood SES and diet and health outcomes is an important step in improving overall health status. Given that Japanese women enjoy the greatest longevity in the world [19], examining health inequalities in neighborhood SES in Japan should provide important insights in this field.

Using data from the Freshmen in Dietetic Courses Study II [20–23], we conducted a cross-sectional study of the association between a neighborhood SES index, recently formulated for Japanese conditions [24], and intake of a wide range of foods and nutrients, as assessed using a previously validated, comprehensive self-administered diet history questionnaire (DHQ) [25–28], and body mass index (BMI) in a group of young Japanese women.

Materials and methods

Data source and study sample

The present study was based on data from the Freshmen in Dietetic Courses Study II, a cross-sectional, self-administered questionnaire survey in dietetic students ($n = 4679$) from 54 institutions (universities, colleges, and technical schools) in 33 of 47 prefectures in Japan. A detailed description of the study design and survey procedure has been published elsewhere [20–23]. Briefly, a set of two questionnaires on dietary habits and other lifestyle behaviors during the preceding month was distributed to all students at orientation sessions or early lectures for freshman students who entered dietetic courses in April 2005, in most institutions within 2 wk after the course began. In accordance with the survey protocol, answered questionnaires were checked at least twice for completeness by trained survey staff (mostly registered dietitians) and, when necessary, forms were reviewed with the subject to ensure the clarity of answers. In total, 4394 students (4186 women and 226 men) completed both questionnaires (response rate 93.9%).

In Japan, all districts belong to a municipality, all of which in turn fall within the boundaries of 1 of 47 prefectures. Tokyo Prefecture (Tokyo metropolis) includes 23 special wards, in addition to cities, towns, and villages, whereas several large cities (cities designated by ordinance) outside Tokyo such as Osaka and Yokohama consist of wards. As of October 1, 2005, the total of 2372 municipalities consisted of the 23 special wards of Tokyo, 141 other wards of 14 cities designated by ordinance, 736 cities, 1178 towns, and 294 villages [29]. Because almost all socioeconomic statistics in Japan are available only at the municipal level, we used municipalities as proxies for neighborhoods. Study participants were linked to their municipalities using their home addresses, as reported in the lifestyle questionnaire.

For the present analysis, we selected female participants 18–20 y of age ($n = 4060$). We then excluded women who were in an institution where the survey was not conducted within 2 wk of entry ($n = 98$), those not providing sufficient information on their home addresses ($n = 46$), those who reported extremely low or high energy intake (<500 or >4000 kcal/d, $n = 21$), and those with missing information on the variables used ($n = 6$). Because some participants were in more than one exclusion category, the final analysis sample consisted of 3892 women who resided in 1033 municipalities dispersed in 47 prefectures in Japan.

This study was approved by the ethics committee of the National Institute of Health and Nutrition, Japan. Participants indicated their informed consent by completing survey questionnaires.

Neighborhood SES index

We constructed a neighborhood SES index at the municipality level using seven variables determined by a comprehensive literature review of previous studies of neighborhood effects [24]. These variables were 1) unemployment (percentage of unemployed persons ≥15 y old), 2) household overcrowding (average floor space per residential dwelling), 3) poverty (number of households receiving public assistance per 1000 households), 4) education (percentage of persons 20–64 y old who had completed up to college or university education), 5) income (total taxable income divided by total population), 6) home ownership (percentage of owned houses to total residential households), and 7) vulnerable groups (percentage of households of a single person ≥65 y old to total households) [24]. For unemployment, household overcrowding, home ownership, and vulnerable groups, data were derived from the 2005 census [29]. Because this census did not include information on the other three variables, data for these were derived from results of other governmental surveys, namely the System of Social and Demographic Statistics of Japan, Basic Data by Municipality (1980–2005) [30] for poverty, the 2000 census [29] for education, and the Indicators of Citizens' Income 2005 [31] for income. Because several municipalities were amalgamated or annexed during the past several years, we annexed data on neighborhood SES and participants' home addresses so that the boundaries of municipalities as of October 1, 2005 (date of the 2005 census) could be used. Because data on poverty were not available for some municipalities ($n = 8$), these were assigned the value of surrounding municipalities.

For each of the seven variables, a Z-score was estimated by subtracting the mean for the total sample of municipalities and dividing by the standard deviation [24]. Because of their skewed distribution, for unemployment, poverty, income, and vulnerable group, were first natural log transformed ($y = \ln[x + 1]$) before calculation of the Z-score. These seven variables were then combined into a neighborhood summary score (i.e., neighborhood SES index) constructed by summing Z-scores for each of the seven variables (Z-scores for household overcrowding, education, income, and home ownership were multiplied by −1 before summing), with a higher neighborhood SES index signifying increasing neighborhood socioeconomic disadvantage [24].

Dietary intake

Dietary habits during the preceding month were assessed using a comprehensive self-administered DHQ. Details of the DHQ's structure, calculation of dietary intake, and validity for commonly studied nutritional factors have been published elsewhere [25–28]. Briefly, the DHQ is a structured 16-page questionnaire that asks about the consumption frequency and portion size of selected foods commonly consumed in Japan, general dietary behavior, and usual cooking methods [25]. Estimates of daily intake for foods (150 items in total), energy, and selected nutrients were calculated using an ad hoc computer algorithm for the DHQ [25,28] based on the Standard Tables of Food Composition in Japan [32]. Dietary glycemic load (a measurement of carbohydrate quality and quantity) was also calculated according to a procedure described elsewhere [20,28,33]. To minimize the influence of dietary misreporting, an ongoing controversy in studies that collect dietary information using self-report instruments [34], values of food and nutrient intake and dietary glycemic load were energy-adjusted using the density method (i.e., percentage of energy for energy-providing nutrients and amount per 1000 kcal of energy for other variables).

Body mass index

Body weight and height were self-reported as part of the DHQ. BMI was calculated as weight (kilograms) divided by the square of height (meters).

Other variables

Based on the reported home address, each participant was grouped into one of six regions (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu) and one of three municipality levels (ward; city; and town and village). The participant was also grouped into one of four institution types (4-y private [private university], 2-y private [private college and technical school], 4-y public [public university], and 2-y public [public college and technical school]) based on the institution she attended and into one of three living statuses (living with family, living alone, and living with others), which was self-reported in the lifestyle questionnaire. Current smoking (yes or no) and current alcohol drinking (yes or no) were self-reported in the lifestyle questionnaire and DHQ, respectively. Physical activity was computed as the average metabolic equivalent-hours score per day [35] on the basis of the frequency and duration of five different activities (sleeping, high- and moderate-intensity activities, walking, and sedentary activities) over the preceding month, as reported in the lifestyle questionnaire [36].

Statistical analysis

All statistical analyses were performed using SAS 9.1 (SAS Institute, Cary, NC, USA). Using the PROC GLM procedure, linear regression models were constructed to examine the association of neighborhood SES index with dietary intake and BMI. For analyses, participants were categorized into quintiles according to neighborhood SES index. Crude and multivariate-adjusted mean values (with 95% confidence intervals) of dietary intake and BMI were calculated by quintile of neighborhood SES index. Potential confounding or mediating factors included in the multivariate models were household SES variables, i.e., institution type [37] and living status [22], and non-dietary lifestyle factors, i.e., current smoking status, current alcohol drinking status, and physical activity (continuous). In the analysis of BMI, dietary factors, i.e., dietary fiber intake (continuous) and dietary glycemic load (continuous), variables significantly associated with BMI in the present population [20], in addition to energy intake (continuous), were also included. In addition, geographic variables, i.e., region and municipality level, were included, in consideration of regional or urban–rural differences in neighborhood SES in Japan observed in previous research [24,38,39]. We tested for linear trends with increasing levels of neighborhood SES index by assigning each participant the median value for the category and modeling this value as a continuous variable. All reported P values are two-tailed, and $P < 0.05$ was considered statistically significant. Because the great majority of municipalities had only a few study participants (median 2, interquartile range 1–4), no special methods were required to account for within-neighborhood correlations in outcomes [6,10,40,41].

Results

Characteristics of participants are listed in Table 1. Overall, participants were characterized by a low BMI, low smoking and alcohol drinking rates, and low total fat and saturated fat intakes.

Neighborhood SES, geographic, household SES, and non-dietary lifestyle characteristics according to quintile of neighborhood SES index are listed in Table 2. Neighborhood SES index was associated with each of the seven neighborhood SES variables in the expected direction. The index was also associated with region, municipality level, institution type, and living status. The higher quintiles of the index (increasing neighborhood socioeconomic disadvantage) included a larger number of participants living in Hokkaido and Tohoku, Kinki, Chugoku and Shikoku, and Kyushu and fewer in Kanto. Hokuriku and Tokai had more participants living in wards and fewer in towns and villages, more participants attending 4-y private and 4-y public institutions and fewer

Table 1
Participant characteristics ($n = 3892$)*

Variable	
Neighborhood socioeconomic status index	0.00 ± 3.81
Percentage of unemployed persons ≥15 y old	5.7 (5.0–6.6)
Average floor space per residential dwelling (m^2)	97.8 ± 25.7
No. of households receiving public assistance (/1000 households)	14.4 (9.2–22.3)
Percentage of persons completing college or university 20–64 y old	31.4 ± 8.5
Total taxable income divided by total population (1000 yen)	1379 (1211–1528)
Percentage of owned houses to total residential households	64.9 ± 13.3
Percentage of households of single persons ≥65 y old to total households	7.1 (5.8–8.8)
Age (y)	18.1 ± 0.3
Body height (m)	1.58 ± 0.05
Body weight (kg)	52.3 ± 7.7
Body mass index (kg/m^2)	21.0 ± 2.8
Current smokers (%)	1.5
Current alcohol drinkers (%)	19.3
Physical activity (total metabolic equivalents-h/d)	34.1 ± 3.7
Energy intake (kcal/d)	1812 ± 503
Food intake (g/1000 kcal)	
Rice, bread, noodles, and potatoes	240.8 ± 64.5
Confectioneries and sugars	38.0 ± 17.4
Fats and oils	13.6 ± 6.6
Pulses and nuts	25.0 ± 18.0
Fish and shellfish, meat, and eggs	82.1 ± 29.7
Dairy products	83.7 ± 71.3
Fruits and vegetables	177.5 ± 101.0
Nutrient intake	
Protein (% energy)	13.3 ± 2.1
Total fat (% energy)	29.5 ± 5.9
Saturated fatty acids (% energy)	8.2 ± 2.1
Carbohydrate (% energy)	55.8 ± 6.8
Dietary fiber (g/1000 kcal)	6.5 ± 2.1
Cholesterol (mg/1000 kcal)	164 ± 64
Dietary glycemic load (/1000 kcal)	82.2 ± 14.7

* Values are means ± SDs or medians (interquartile ranges) unless otherwise indicated.

attending 2-y private and 2-y public institutions, and more participants living alone or with others and fewer living with family. No association was seen between neighborhood SES index and current smoking status, current alcohol drinking status, or physical activity.

Dietary characteristics according to quintile of neighborhood SES index are presented in Table 3. The index was not associated with any dietary variable examined, with the exception of a negative association with pulses and nuts and dairy products. Adjustment for possible confounding or mediating factors, including household SES (institution type and living status), non-dietary lifestyle (current smoking, current alcohol drinking, and physical activity), and geographic (region and municipality level) variables did not change the results materially with the exception of the loss of association for dairy products (data not shown).

Body mass index according to quintile of neighborhood SES index is presented in Table 4. Higher neighborhood SES index (increasing neighborhood socioeconomic disadvantage) was significantly associated with higher BMI, although the magnitude of differences in BMI between quintiles of neighborhood SES index was somewhat small. This significant association remained after adjustment for possible confounding or mediating factors, including household SES, non-dietary lifestyle, dietary (energy intake, dietary fiber intake, and dietary glycemic load), and geographic variables.

Discussion

In this cross-sectional study of a group of young Japanese women, we found that neighborhood SES was not materially associated with dietary intake, but that increasing neighborhood socioeconomic disadvantage was associated with increasing BMI. This association between neighborhood SES and BMI was independent of possible confounding or mediating factors, including household SES, non-dietary lifestyle, dietary, and geographic variables. To our knowledge, this is the first study to investigate the association between neighborhood SES and dietary intake or BMI in a Japanese population.

In Western populations, neighborhood socioeconomic disadvantages have been consistently associated with poor diet, including lower fruit and vegetable consumption [3–6]. In this study of young Japanese women, conversely, we saw no material association between neighborhood SES and intake of foods and nutrients. The reason for the present findings is unknown. Considering that Japan has long been shown to have lower inequality in individual SES than other developed countries [42], inequalities in neighborhood SES in Japan may be too low to have a measurable influence on dietary habits. Alternatively, the homogenous characteristics of participants in terms of individual SES (i.e., Japanese female dietetic students 18–20 y of age) may have hampered the identification of any meaningful association between neighborhood SES and dietary intake.

Consistent with previous Western studies [7–10], however, we did identify an association between neighborhood socioeconomic disadvantage and higher BMI. There are several proximate mechanisms through which neighborhood characteristics could be hypothesized to influence the development of obesity [10]. Neighborhood SES may be related to BMI through influencing behaviors linked to diet and physical activity [8,10,43]. This is unlikely in the present study, however, because neighborhood SES was not associated with physical activity or dietary factors and the association between neighborhood SES and BMI remained after adjustment for physical activity and dietary factors. Alternatively, neighborhood SES may be related to BMI through chronic stress on the basis that, although sources of chronic stress (such as noise, violence, poverty, vigilance, threat, and alarm) are likely to vary across neighborhoods, chronic stress may be related to the development of obesity through endocrine pathways involving the hypothalamo-pituitary-adrenal axis or activation of the sympathetic nervous system, although

Table 2
Neighborhood socioeconomic status, geographic, household socioeconomic status, and non-dietary lifestyle characteristics according to quintile category of neighborhood socioeconomic status index ($n = 3892$)*

Variable	Quintile 1 ($n = 778$)	Quintile 2 ($n = 779$)	Quintile 3 ($n = 777$)	Quintile 4 ($n = 783$)	Quintile 5 ($n = 775$)	$P^{\dagger}$
Neighborhood socioeconomic status index, median (range)	−4.40 (−15.72 to −3.01)	−1.93 (−3.00 to −1.24)	−0.31 (−1.23 to 0.67)	1.70 (0.68–3.01)	5.00 (3.02–22.43)	—
Percentage of unemployed persons aged ≥15 y‡	4.6 (4.5–4.6)	5.2 (5.2–5.3)	5.6 (5.5–5.7)	6.2 (6.2–6.3)	7.4 (7.3–7.5)	<0.0001
Average floor space per residential dwelling (m²)	118.2 (116.0–120.3)	101.7 (100.1–103.3)	96.4 (94.8–98.0)	90.9 (89.7–92.2)	81.8 (80.6–83.0)	<0.0001
No. of households receiving public assistance (/1000 households)‡	6.0 (5.7–6.2)	10.6 (10.3–10.8)	14.7 (14.4–15.1)	18.5 (18.1–18.9)	32.6 (31.7–33.6)	<0.0001
Percentage of persons completing college or university aged 20–64 y	33.3 (32.6–34.0)	32.1 (31.5–32.7)	32.4 (31.8–33.1)	31.3 (30.8–31.8)	27.9 (27.5–28.3)	<0.0001
Total taxable income divided by total population (1000 yen)‡	1465 (1440–1490)	1403 (1384–1422)	1411 (1389–1433)	1326 (1309–1344)	1197 (1179–1215)	<0.0001
Percentage of owned houses to total residential households	73.6 (72.7–74.4)	68.7 (67.8–69.5)	64.8 (64.0–65.6)	61.2 (60.4–62.0)	56.3 (55.5–57.2)	<0.0001
Percentage of households of single persons aged ≥65 y to total households‡	5.5 (5.4–5.6)	6.2 (6.1–6.3)	7.1 (7.0–7.2)	8.1 (8.0–8.2)	9.8 (9.6–10.0)	<0.0001
Region (%)						<0.0001
Hokkaido and Tohoku	6.2	4.8	6.6	16.0	15.0	
Kanto	36.3	55.7	43.1	26.7	10.2	
Hokuriku and Tokai	36.8	15.4	14.7	1.9	0.9	
Kinki	16.2	13.4	22.7	22.6	24.1	
Chugoku and Shikoku	2.8	9.1	8.5	20.3	13.2	
Kyushu	1.8	1.7	4.5	12.5	36.7	
Municipality level (%)						<0.0001
Ward	14.8	8.9	11.6	25.9	35.7	
City	55.4	75.5	76.2	65.1	55.4	
Town and village	29.8	15.7	12.2	8.9	8.9	
Institution type (%)						<0.0001
4-y private (private university)	40.0	45.6	53.7	55.8	65.7	
2-y private (private college and technical school)	52.1	44.0	38.4	38.4	26.2	
4-y public (public university)	4.9	3.1	3.1	5.1	8.1	
2-y public (public college and technical school)	3.1	7.3	4.9	0.6	0.0	
Living status (%)						0.0060
Living with family	91.5	89.4	88.3	87.1	87.0	
Living alone	6.7	7.8	10.8	10.6	10.5	
Living with others	1.8	2.8	0.9	2.3	2.6	
Current smokers (%)	1.5	1.7	1.4	1.7	1.2	0.58
Current alcohol drinkers (%)	18.5	17.8	19.6	18.9	21.7	0.10
Physical activity (total metabolic equivalents-h/d)	33.8 (33.6–34.1)	34.2 (34.0–34.5)	34.3 (34.0–34.6)	34.3 (34.0–34.6)	34.1 (33.9–34.3)	0.22

* Values are means (95% confidence intervals) unless otherwise indicated.
† For continuous variables, a linear trend test was used with the median value in each quintile category as a continuous variable in linear regression; for categorical variables, a Mantel-Haenszel chi-square test was used.
‡ Calculated using back transformation of natural-log–transformed values.

evidence for this in humans is not yet conclusive [8,10,44,45]. Our results are consistent with this environmental stress theory for the role of the environment in obesity, although the association remains speculative because no variables associated with chronic stress were included in the present study. Although the magnitude of differences in BMI between quintiles of neighborhood SES index was somewhat small, the finding is important from a public health perspective, given the difficulty faced by individuals living in disadvantaged neighborhoods to improve the local environment.

Several limitations of the present study deserve mention. First, participants were selected female dietetic students, not a random sample of Japanese people. To minimize the influence of nutritional education, the present survey was conducted in most institutions within 2 wk after the course began. Nevertheless, these participants may have healthier dietary habits than the general population, although, with regard to the intake of fat and carbohydrate and BMI at least, mean values in the present study were reasonably comparable to those of a representative sample of Japanese women 15–19

Table 3
Dietary characteristics according to quintile category of neighborhood socioeconomic status index ($n = 3892$)*

Variable	Quintile 1 ($n = 778$)	Quintile 2 ($n = 779$)	Quintile 3 ($n = 777$)	Quintile 4 ($n = 783$)	Quintile 5 ($n = 775$)	$P^{\dagger}$
Energy intake (kcal/d)	1844 (1808–1879)	1785 (1752–1819)	1826 (1789–1863)	1822 (1785–1858)	1785 (1750–1820)	0.10
Food intake (g/1000 kcal)						
Rice, bread, noodles, and potatoes	239.7 (235.2–244.2)	240.7 (236.2–245.3)	241.4 (236.9–245.9)	237.6 (233.1–242.0)	244.5 (239.8–249.2)	0.28
Confectioneries and sugars	37.2 (36.1–38.3)	37.9 (36.7–39.1)	38.7 (37.5–39.9)	39.2 (38.0–40.4)	36.7 (35.5–38.0)	0.88
Fats and oils	14.0 (13.5–14.5)	13.4 (13.0–13.8)	13.0 (12.6–13.4)	14.0 (13.5–14.5)	13.5 (13.0–13.9)	0.52
Pulses and nuts	26.2 (24.9–27.5)	25.7 (24.4–27.0)	24.4 (23.2–25.5)	24.7 (23.4–26.0)	24.1 (22.9–25.3)	0.011
Fish and shellfish, meat, and eggs	82.7 (80.7–84.8)	80.9 (78.9–83.0)	80.0 (78.0–82.0)	82.5 (80.4–84.6)	84.6 (82.4–86.8)	0.08
Dairy products	84.3 (79.4–89.3)	89.2 (83.8–94.6)	86.2 (81.4–91.1)	81.6 (76.7–86.5)	77.1 (72.2–82.0)	0.0055
Fruits and vegetables	176.9 (170.1–183.6)	179.0 (171.6–186.4)	182.9 (175.5–190.4)	168.9 (162.3–175.4)	180.0 (172.7–187.4)	0.88
Nutrient intake						
Protein (% energy)	13.4 (13.2–13.5)	13.3 (13.2–13.5)	13.3 (13.1–13.4)	13.3 (13.1–13.4)	13.4 (13.2–13.5)	0.99
Total fat (%energy)	29.8 (29.3–30.2)	29.3 (28.9–29.7)	29.2 (28.8–29.7)	29.9 (29.5–30.4)	29.2 (28.8–29.6)	0.36
Saturated fatty acids (% energy)	8.3 (8.1–8.4)	8.2 (8.1–8.3)	8.2 (8.1–8.4)	8.3 (8.2–8.5)	8.0 (7.9–8.2)	0.10
Carbohydrate (% energy)	55.6 (55.1–56.1)	56.0 (55.6–56.5)	56.2 (55.7–56.6)	55.3 (54.9–55.8)	55.8 (55.3–56.3)	0.81
Dietary fiber (g/1000 kcal)	6.6 (6.4–6.7)	6.5 (6.4–6.7)	6.6 (6.5–6.8)	6.4 (6.2–6.5)	6.6 (6.4–6.7)	0.69
Cholesterol (mg/1000 kcal)	165 (160–169)	161 (157–165)	161 (157–166)	166 (161–171)	167 (162–171)	0.20
Dietary glycemic load (/1000 kcal)	81.9 (80.8–82.9)	82.7 (81.7–83.8)	82.5 (81.5–83.5)	81.6 (80.6–82.6)	82.4 (81.3–83.4)	0.93

* Values are means (95% confidence intervals).

† A linear trend test was used with the median value in each quintile category as a continuous variable in linear regression. Adjustment for possible confounding or mediating variables, including institution type (4-y private [private university], 2-y private [private college and technical school], 4-y public [public university], and 2-y public [public college and technical school]), living status (living with family, living alone, and living with others), current smoking (yes or no), current alcohol drinking (yes or no), physical activity (total metabolic equivalents-hours/day, continuous), region (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu), and municipality level (ward; city; and town and village), did not change the results materially, with the exception of a non-significant association for dairy products.

y of age (30.3% of energy, 54.5% of energy, and 21.1 kg/m^2, respectively; data not available for other dietary variables) [46]. Thus, our results might not be extrapolated to the general Japanese population.

Second, research on neighborhoods is limited by the need to operationalize the complex conceptual construct represented by geographic space [4]. Because participants were dispersed in all 47 prefectures in Japan, we relied on census-based measurements at the municipality level as proxies for neighborhoods, which may not correspond to socially defined neighborhoods. In addition, municipality in Japan may be a somewhat large unit for neighborhoods, given that the median population of 1033 municipalities was 153 639 (interquartile range 60 884–291 027). Our study is also limited by the use of the neighborhood SES score as an indirect proxy for the specific features of neighborhoods that may be more relevant [10].

Third, we used a self-administered semiquantitative dietary assessment questionnaire (i.e., DHQ) for dietary data collection. Although this questionnaire has been validated [25–28], actual dietary habits were not observed. Thus, although energy-adjusted values of dietary intake were used to minimize the influence of measurement errors derived from self-reported dietary behavior [34], the results should nevertheless be interpreted with caution.

Fourth, we used BMI values calculated from self-reported body weight and height, which might be biased. However, previous studies have shown that BMI calculated from

Table 4
Body mass index according to quintile category of neighborhood socioeconomic status index ($n = 3892$)*

Variable	Quintile 1 ($n = 778$)	Quintile 2 ($n = 779$)	Quintile 3 ($n = 777$)	Quintile 4 ($n = 783$)	Quintile 5 ($n = 775$)	$P^{\dagger}$
Crude model	20.9 (20.7–21.1)	20.8 (20.6–21.0)	20.9 (20.7–21.1)	21.1 (20.9–21.3)	21.1 (20.9–21.3)	0.020
Multivariate model‡	20.8 (20.6–21.0)	20.8 (20.6–21.0)	21.0 (20.8–21.2)	21.1 (20.9–21.3)	21.1 (20.9–21.3)	0.037

* Values are means (95% confidence intervals).

† A linear trend test was used with the median value in each quintile category as a continuous variable in linear regression.

‡ Adjusted for institution type (4-y private [private university], 2-y private [private college and technical school], 4-y public [public university], and 2-y public [public college and technical school]), living status (living with family, living alone, and living with others), current smoking (yes or no), current alcohol drinking (yes or no), physical activity (total metabolic equivalents-hours/day, continuous), energy intake (kilocalories per day, continuous), dietary fiber intake (grams per 1000 kcal, continuous), dietary glycemic load (per 1000 kcal, continuous), region (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu), and municipality level (ward; city; and town and village).

self-reported values is highly correlated with BMI calculated from measured values [47,48], and it is therefore suggested that BMI calculated from self-reported weight and height is a reliable measurement for use in association analysis at least.

Fifth, although we attempted to adjust for a variety of potential confounding (or mediating) variables, we cannot rule out residual confounding due to poorly measured (e.g., physical activity, which was assessed relatively roughly from only five activities) and unmeasured (e.g., household income, which was unfortunately unavailable in the present study, but may be at least partly reflected by institution type and living status) variables. Finally, the cross-sectional nature of the study hampers the drawing of conclusions on any causal inferences between neighborhood SES and diet and BMI.

Conclusion

Although no material association was seen between neighborhood SES and dietary intake, increasing neighborhood socioeconomic disadvantage was independently associated with increasing BMI in a group of young Japanese women. Efforts to reduce inequalities in neighborhood SES may be an important strategy in improving the health status of individuals.

References

[1] de Castro JM, Taylor T. Smoking status relationships with the food and fluid intakes of free-living humans. Nutrition 2008;24:109–19.
[2] Escurriol V, Mari-Dell'Olmo M, Rohlfs I, Borrell C, Chirlaque MD, Buckland G, et al. Plant sterol intake and education level in the Spanish EPIC cohort. Nutrition 2009;25:769–73.
[3] Diez-Roux AV, Nieto FJ, Caulfield L, Tyroler HA, Watson RL, Szkio M. Neighbourhood differences in diet: the Atherosclerosis Risk in Communities (ARIC) Study. J Epidemiol Community Health 1999;53:55–63.
[4] Dubowitz T, Heron M, Bird CE, Lurie N, Finch BK, Basurto-Davila R, et al. Neighborhood socioeconomic status and fruit and vegetable intake among whites, blacks, and Mexican Americans in the United States. Am J Clin Nutr 2008;87:1883–91.
[5] Shohaimi S, Welch A, Bingham S, Luben R, Day N, Wareham N, et al. Residential area deprivation predicts fruit and vegetable consumption independently of individual educational level and occupational social class: a cross sectional population study in the Norfolk cohort of the European Prospective Investigation into Cancer (EPIC-Norfolk). J Epidemiol Community Health 2004;58:686–91.
[6] Stimpson JP, Nash AC, Ju H, Eschbach K. Neighborhood Deprivation is associated with lower levels of serum carotenoids among adults participating in the Third National Health and Nutrition Examination Survey. J Am Diet Assoc 2007;107:1895–902.
[7] Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. J Epidemiol Community Health 2007;61:491–8.
[8] Glass TA, Rasmussen MD, Schwartz BS. Neighborhoods and obesity in older adults: the Baltimore Memory Study. Am J Prev Med 2006; 31:455–63.
[9] Black JL, Macinko J. Neighborhoods and obesity. Nutr Rev 2008; 66:2–20.
[10] Diez Roux AV, Jacobs DR, Kiefe CI. Neighborhood characteristics and components of the insulin resistance syndrome in young adults: the Coronary Artery Risk Development in Young Adults (CARDIA) study. Diabetes Care 2002;25:1976–82.
[11] Martikainen P, Ishizaki M, Marmot MG, Nakagawa H, Kagamimori S. Socioeconomic differences in behavioural and biological risk factors: a comparison of a Japanese and an English cohort of employed men. Int J Epidemiol 2001;30:833–8.
[12] Nishi N, Makino K, Fukuda H, Tatara K. Effects of socioeconomic indicators on coronary risk factors, self-rated health and psychological well-being among urban Japanese civil servants. Soc Sci Med 2004; 58:1159–70.
[13] Hirokawa K, Tsutusmi A, Kayaba K. Impacts of educational level and employment status on mortality for Japanese women and men: the Jichi Medical School cohort study. Eur J Epidemiol 2006;21:641–51.
[14] Winkleby MA, Jatulis DE, Frank E, Fortmann SP. Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. Am J Public Health 1992; 82:816–20.
[15] Lantz PM, House JS, Lepkowski JM, Williams DR, Mero RP, Chen J. Socioeconomic factors, health behaviors, and mortality: results from a nationally representative prospective study of US adults. JAMA 1998;279:1703–8.
[16] Lahelma E, Martikainen P, Laaksonen M, Aittomaaki A. Pathways between socioeconomic determinants of health. J Epidemiol Community Health 2004;58:327–32.
[17] Irala-Estevez JD, Groth M, Johansson L, Oltersdorf U, Prattala R, Martinez-Gonzalez MA. A systematic review of socio-economic differences in food habits in Europe: consumption of fruit and vegetables. Eur J Clin Nutr 2000;54:706–14.
[18] Darmon N, Drewnowski A. Does social class predict diet quality? Am J Clin Nutr 2008;87:1107–17.
[19] Wilkinson RG. National mortality rates: the impact of inequality? Am J Public Health 1992;82:1082–4.
[20] Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. for the Freshmen in Dietetic Courses Study II Group. Dietary fiber intake, dietary glycemic index and load, and body mass index: a cross-sectional study of 3931 Japanese women aged 18–20 years. Eur J Clin Nutr 2007;61:986–95.
[21] Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. for the Freshmen in Dietetic Courses Study II Group. Food intake and functional constipation: a cross-sectional study of 3,835 Japanese women aged 18–20 years. J Nutr Sci Vitaminol 2007;53:30–6.
[22] Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. Monetary costs of dietary energy reported by young Japanese women: association with food and nutrient intake and body mass index. Public Health Nutr 2007;10:1430–9.
[23] Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. for the Freshmen in Dietetic Courses Study II Group. Association between dietary fiber, water and magnesium intake and functional constipation among young Japanese women. Eur J Clin Nutr 2007;61:616–22.
[24] Fukuda Y, Nakamura K, Takano T. Higher mortality in areas of lower socioeconomic position measured by a single index of deprivation in Japan. Public Health 2007;121:163–73.
[25] Sasaki S, Yanagibori R, Amano K. Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. J Epidemiol 1998;8:203–15.
[26] Sasaki S, Yanagibori R, Amano K. Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-hour urinary excretion. Jpn Circ J 1998;62:431–5.
[27] Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y, et al. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. J Nutr Sci Vitaminol 2000; 46:285–96.
[28] 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.

[29] Statistics Bureau, Ministry of Internal Affairs and Communications, Japan. E-Stat (in Japanese). Available at: http://www.e-stat.go.jp/SG1/estat/eStatTopPortal.do. Accessed August 6, 2008.
[30] Statistics Bureau, Ministry of Internal Affairs and Communications, Japan. System of social and demographic statistics of Japan. Basic data by municipality (1980–2005) (in Japanese). Tokyo: Statistics Bureau, Ministry of Internal Affairs and Communications, Japan; 2007.
[31] Society for the Study of Municipal Taxation. Indicators of citizen's income 2005 (in Japanese). Tokyo: JPS Co. Ltd; 2006.
[32] Science and Technology Agency. Standard tables of food composition in Japan (in Japanese). 5th rev enlarged. Tokyo: Printing Bureau of the Ministry of Finance; 2005.
[33] Murakami K, Sasaki S, Takahashi Y, Okubo H, Hosoi Y, Horiguchi H, et al. Dietary glycemic index and load in relation to metabolic risk factors in Japanese female farmers with traditional dietary habits. Am J Clin Nutr 2006;83:1161–9.
[34] Murakami K, Sasaki S, Takahashi Y, Uenishi K, Yamasaki M, Hayabuchi H, et al. Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women. Eur J Clin Nutr 2008;62:111–8.
[35] Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, et al. Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 1993;25:71–80.
[36] Murakami K, Sasaki S, Takahashi Y, Uenishi K. for the Japan Dietetic Students' Study for Nutrition and Biomarkers Group. Dietary energy density is associated with body mass index and waist circumference, but not with other metabolic risk factors, in free-living young Japanese women. Nutrition 2007;23:798–806.
[37] Karvonen S, Rimpela A. Socio-regional context as a determinant of adolescents' health behaviour in Finland. Soc Sci Med 1996;43:1467–74.
[38] Fukuda Y, Nakamura K, Takano T. Municipal socioeconomic status and mortality in Japan: sex and age differences, and trends in 1973–1998. Soc Sci Med 2004;59:2435–45.
[39] Fukuda Y, Nakamura K, Takano T. Cause-specific mortality differences across socioeconomic position of municipalities in Japan, 1973–1977 and 1993–1998: increased importance of injury and suicide in inequality for ages under 75. Int J Epidemiol 2005;34:100–9.
[40] Duncan C, Jones K, Moon G. Context, composition and heterogeneity: using multilevel models in health research. Soc Sci Med 1998; 46:97–117.
[41] Robert SA. Community-level socioeconomic status effects on adult health. J Health Soc Behav 1998;39:18–37.
[42] Pickett KE, Kelly S, Brunner E, Lobstein T, Wilkinson RG. Wider income gaps, wider waistbands? An ecological study of obesity and income inequality. J Epidemiol Community Health 2005; 59:670–4.
[43] Booth SL, Sallis JF, Ritenbaugh C, Hill JO, Birch LL, Frank LD, et al. Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. Nutr Rev 2001;59(3 pt 2):S21–39.
[44] Bjorntorp P, Rosmond R. Hypothalamic origin of the metabolic syndrome X. Ann N Y Acad Sci 1999;892:297–307.
[45] Chrousos GP. The role of stress and the hypothalamic-pituitary-adrenal axis in the pathogenesis of the metabolic syndrome: neuro-endocrine and target tissue-related causes. Int J Obes Relat Metab Disord 2000; 24(suppl 2):S50–5.
[46] Ministry of Health. Labour and Welfare of Japan. The National Health and Nutrition Survey in Japan, 2005 (in Japanese). Tokyo: Daiichi Shuppan Publishing Co., Ltd.; 2008.
[47] Nakamura K, Hoshino Y, Kodama K, Yamamoto M. Reliability of self-reported body height and weight of adult Japanese women. J Biosoc Sci 1999;31:555–8.
[48] Wada K, Tamakoshi K, Tsunekawa T, Otsuka R, Zhang H, Murata C, et al. Validity of self-reported height and weight in a Japanese workplace population. Int J Obes Relat Metab Disord 2005;29:1093–9.

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Iron intake does not significantly correlate with iron deficiency among young Japanese women: a cross-sectional study

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Abstract

Objectives: We evaluated the association of nutrient intake with Fe deficiency with regard to lifestyle factors and health condition in young Japanese women. Uniquely among developed countries, dietary habits render Japanese populations vulnerable to Fe deficiency, owing to their relatively low intake of Fe and high intake of Fe absorption inhibitors, such as green tea and soyabeans.
Design: A cross-sectional study.
Setting and subjects: The subjects were 1019 female Japanese dietetic students aged 18–25 years. Dietary habits during the preceding month were assessed using a previously validated, self-administered, diet history questionnaire. Blood analysis was performed to assess body Fe status. Subjects were categorized with Fe deficiency when their serum ferritin levels were <12 ng/ml. Twenty-nine dietary variables, i.e. intakes of energy, sixteen nutrients including Fe and twelve food groups, were analysed using multivariate logistic regression models adjusted for possible confounders.
Results: Of the subjects, 24·5 % were categorized with Fe deficiency. However, no dietary factors assessed were significantly associated with Fe deficiency. The risk of Fe deficiency was significantly lower in women with infrequent or no menstrual cycles than in those with regular cycles (OR = 0·58; 95 % CI 0·34, 1·00) and significantly higher in women with heavy menstrual flow than in women with average flow, albeit that these were self-reported (OR = 1·83; 95 % CI 1·35, 2·48).
Conclusions: These results suggest that dietary habits, including Fe intake, do not significantly correlate with Fe deficiency among young Japanese women.

Keywords
Iron intake
Iron deficiency
Menstrual condition
Young Japanese women

Fe deficiency remains the most common nutritional deficiency in both developed and developing countries, particularly among adolescent and premenopausal women. In developed countries, for example, the prevalence of Fe deficiency, including depleted Fe stores and Fe deficiency anaemia, among young and middle-aged women is 11 % in the USA[1] and 18 % in the UK[2]. Moreover, in Japan, Uchida *et al.* reported in 1992 a prevalence of depleted Fe stores of 41·4 % and of Fe deficiency anaemia of 8·5 % among women aged 11–90 years[3]. Fe deficiency has been related with impaired neuropsychological function[4], reduced worker productivity[5], lowered immunity and decreased metabolic rate[6]. Further, Fe deficiency anaemia in pregnancy often contributes to higher child and maternal mortality[7] as well as increased risk of preterm delivery[8]. Given that supplementation is considered the most effective treatment, the most common response has been Fe

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fortification of white flour and other foods, mainly in Western countries.

Several studies in Western countries have reported the important effect of dietary habits on body Fe status[9–11]. These studies have shown that increasing total or haem Fe intake correlates with better body Fe status; in other words, higher intake of Fe is associated with a lower prevalence of Fe deficiency. In apparent contradiction, however, Pynaert *et al.* recently reported the lack of any significant differences in Fe status parameters between women with high and low Fe intake[12], and called for reconfirmation of the efficacy of increasing Fe intake to improve Fe status.

In addition to Fe itself, several other dietary factors are also known to be associated with Fe levels in man. Absorption is improved by vitamin C and animal tissues such as meat, poultry and fish, but inhibited by phytate, polyphenols, vegetable proteins and Ca[2]. Several lifestyle factors also have considerable effects on body Fe status. Intensive sports and excessive menstrual blood loss are important risk factors for Fe deficiency[13,14]. In particular, menstrual blood loss is thought to be a major cause of deficiency in women[9,14–16].

To our knowledge, however, no study has examined the correlation between Fe status and dietary intake measured quantitatively with respect to lifestyle factors and health condition in Asia. Foo *et al.* examined Fe status and dietary Fe intake among Malaysian adolescents aged 12–19 years[17], but did not describe the association between Fe status and Fe intake; while Thankachan *et al.* showed that inadequate intake of Fe and micronutrients is responsible for the high prevalence of Fe deficiency in India[18], but did not refer to lifestyle factors. Thus, the association of dietary habits with Fe deficiency in consideration of lifestyle factors is not clearly known in Asia, including Japan.

Because it combines Asian dietary habits with a level of development comparable to that of Western countries, Japan may be considered unique among Asian countries. Major distinctions of Japanese dietary habits related to Fe intake include lower meat consumption, which results in lower total Fe intake, particularly lower haem Fe intake, vis-à-vis the intake of higher amounts and a wider range of inhibitors of Fe absorption, such as soyabeans and green tea, which are traditional Japanese foods[19–25]. In the present study, we examined the association of Fe deficiency and quantitative dietary intake with regard to lifestyle and health-related factors in Japan.

Methods

Subjects

The present study was based on a multi-centre nutritional survey conducted from February to March 2006 and from January to March 2007 among female dietetic students from fifteen institutions in Japan. All measurements at each institution were conducted according to the survey protocol. Briefly, staff at each institution explained an outline of the survey to potential subjects. Subjects who responded positively were then provided detailed written and oral explanations of the general purpose and procedure of the survey. A total of 1176 women (474 women in 2006 and 702 women in 2007) took part in the survey. The study protocol was approved by the Ethics Committee of the National Institute of Health and Nutrition, and written informed consent was obtained from each subject and also from a parent for subjects aged less than 20 years.

Dietary assessment

Dietary habits during the preceding month were assessed using a previously validated, comprehensive, self-administered diet history questionnaire (DHQ)[26–29]. All answered DHQ, as well as a lifestyle questionnaire, were checked at least twice for completeness and when necessary reviewed with the subject to ensure the clarity of answers.

The DHQ is a 16-page structured questionnaire that consists of the following seven sections: (i) general dietary behaviour; (ii) major cooking methods; (iii) consumption frequency and amount of six alcoholic beverages; (iv) consumption frequency and semi-quantitative portion size of 122 selected food and non-alcoholic beverage items; (v) dietary supplements; (vi) consumption frequency and semi-quantitative portion size of nineteen cereals usually consumed as staple foods (rice, bread and noodles) and miso (fermented soyabean paste) soup; and (vii) open-ended items for foods consumed regularly (at least once per week) but not appearing in the DHQ. Items and portion sizes were derived primarily from data in the National Nutrition Survey of Japan and several recipe books for Japanese dishes[27]. Information on dietary supplements, including Fe supplements, and data from open-ended questionnaire items were not used in the dietary intake calculation. Estimates of dietary intake for a total of 150 food items, energy and selected nutrients were calculated using an *ad hoc* computer algorithm for the DHQ, based on the *Standard Tables of Food Composition in Japan*[30]. Nutrient and food intakes were energy-adjusted using the density method, i.e. percentage of energy for energy-providing nutrients and amounts per 4184 kJ (1000 kcal) of energy for other nutrients and foods.

A detailed description of the validity of the DHQ with respect to commonly studied nutritional factors and the methods used to calculate dietary intake have been published elsewhere[26–29]. For example, Pearson's correlation coefficients between the DHQ and 3 d estimated dietary records were 0·48 for energy, 0·48 for protein, 0·55 for fat, 0·48 for carbohydrate and 0·40 for Fe in forty-seven women[27]. Further, Pearson's correlation coefficients between the DHQ and 16 d weighed dietary records among ninety-two women were 0·32 for energy, 0·47 for protein, 0·56 for fat, 0·60 for carbohydrate and 0·63 for Fe (S Sasaki, unpublished results). These correlation coefficients are acceptable, because they are similar to those of other self-administered dietary assessment methods developed and widely used in other countries.

Intakes of haem Fe, non-haem Fe, phytate and bioavailable Fe were estimated using DHQ data. Haem Fe was assumed to constitute 40 % of total Fe[31], including that in meat and fish. The remaining total Fe intake was assumed to be non-haem Fe. Because we had insufficient information on the phytate content in Japanese food, we used dietary composition data from other countries[32–35]. Bioavailable Fe is the amount of Fe actually absorbed and utilized in the body, and is determined by several factors, including intake of phytate, Ca, vitamin C, meat, fish, tea and coffee and the individual's Fe status. Of several algorithms developed to estimate bioavailable Fe[31,36–40], we estimated its intake based on that by Bhargava *et al.*[37] (Table 1). Briefly, total bioavailable Fe was obtained by summing bioavailable haem Fe and bioavailable non-haem Fe, with bioavailable haem Fe calculated by multiplying haem Fe intake by a constant determined in accordance with the individual's Fe status. Three possible scenarios of body Fe reserve were considered: (i) 500 mg (adequate reserve); (ii) 250 mg (median reserve), at which functional alterations due to Fe deficiency had likely not occurred; and (iii) 0 mg, at which functional alterations might already have become apparent. Bioavailability of non-haem Fe was calculated for each body Fe reserve by multiplying bioavailability derived from adjustment for an enhancement factor and bioavailability derived from adjustment for phytate. The enhancement factor was obtained by summing the intake of meat (g), fish (g) and vitamin C (mg)[36]. Bioavailable non-haem Fe was derived from the product of non-haem Fe intake and bioavailability of non-haem Fe. In addition, we adjusted for the effect of black tea and coffee, as well as for that of Ca, using the algorithm of Zijp *et al.*[41]. Bioavailability of non-haem Fe was multiplied by 0·8 if intake of black tea and coffee was 450 ml/d or more, and total bioavailable Fe was multiplied by 0·5 if Ca intake was more than 300 mg/d.

Diagnostic criteria of depleted Fe stores and Fe deficiency anaemia

Body Fe status was assessed using blood analysis for serum Fe, ferritin and Hb concentrations. In accordance with the survey protocol, blood samples were transported

Table 1 Algorithm for the estimation of bioavailable iron intake*

1.	Total bioavailable Fe (mg): If Ca intake is ≤300 mg/d Total bioavailable Fe = bioavailable haem Fe (BHI) (mg) + bioavailable non-haem Fe (BNI) (mg) If Ca intake is >300 mg/d Total bioavailable Fe = (BHI + BNI) × 0·5†
2.	BHI=haem Fe intake (mg) × 0·23 (body Fe reserve = 500 mg) × 0·28 (body Fe reserve = 250 mg) × 0·35 (body Fe reserve = 0 mg)
2.1.	Haem Fe intake‡ (mg) = Fe intake from meat, fish and poultry (mg) × 0·4
3.	BNI = non-haem Fe intake (mg) × bioavailabitity of non-haem Fe (BANI) (%)/100
3.1.	Non-haem Fe intake (mg) = total Fe intake − haem Fe intake
3.2.	BANI = bioavailability derived from adjustment for EF§ × bioavailability derived from adjustment for phytates × bioavailability derived from adjustment for black tea & coffee
3.2.1.	Bioavailability derived from adjustment for EF (BAEF) (%): If EF ≥ 75 units, BAEF = 8 (body Fe reserve = 500 mg) = 12 (body Fe reserve = 250 mg) = 20 (body Fe reserve = 0 mg) If EF = 0 units, BAEF = 3 (body Fe reserve = 500 mg) = 4 (body Fe reserve = 250 mg) = 5 (body Fe reserve = 0 mg) If EF > 0 and < 75 units, BAEF = 3 + 8·93 $\log_n$[(EF + 100)/100] (body Fe reserve = 500 mg) = 4 + 14·296 $\log_n$[(EF + 100)/100] (body Fe reserve = 250 mg) = 5 + 26·804 $\log_n$[(EF + 100)/100] (body Fe reserve = 0 mg)
3.2.2.	Bioavailability derived from adjustment for phytates (BAP) (%): If phytates intake is ≤2·88 mg, BAP = 100 If phytates intake is >2·88 mg, $\log_{10}$BAP = −0·2869 $\log_{10}$[phytates intake (mg)] + 0·1295
3.2.3.	Bioavailability derived from adjustment for black tea & coffee (BATC): If the intake of black tea & coffee is ≥450 ml/d, BATC = 0·8†

*Mainly derived from the algorithm reported by Bhargava *et al.*[37].
†From Zijp *et al.*[41].
‡Eggs and dairy products are included in non-haem Fe.
§EF = vitamin C (mg) + meat (g); 'meat' includes meat, fish and poultry.

at −20°C by car or aeroplane to ensure delivery to a laboratory in Tokyo, Japan (SRL Inc. in 2006 and Mitsubishi Kagaku Bio-Clinical Laboratories Inc. in 2007) and assayed within 1–2 d of collection to avoid significant degradation. The colorimetric method (Nitroso-PSAP method) was used to measure serum Fe, and chemiluminescent enzyme immunoassay (CLEIA method) to measure serum ferritin.

Depleted Fe stores was diagnosed when serum ferritin levels were <12 ng/ml and Hb concentrations were ≥12 g/dl; and Fe deficiency anaemia when serum ferritin levels were <12 ng/ml and Hb concentrations were <12 g/dl[42,43]. 'Fe deficiency' included both depleted Fe stores and Fe deficiency anaemia.

Other variables

Residential areas were grouped into three categories: (i) north (Hokkaido, Tohoku and Kanto); (ii) central (Tokai, Hokuriku, and Kinki); and (iii) south (Kyushu and Chugoku), based on the regional blocks used in the National Nutrition Survey in Japan (hereafter referred to as 'residential block'). They were also grouped into three categories according to population size: (i) city with population ≥1 million; (ii) city with population <1 million; and (iii) town or village (hereafter referred to as 'size of residential area'). Current smoking status was self-reported in the lifestyle questionnaire, while current dietary supplement use and alcohol intake were assessed in the DHQ. Alcohol drinking status was divided into three categories: (i) non-drinker; (ii) drinker 1 (>0 % to <1 % of total energy intake); and (iii) drinker 2 (≥1 % of total energy intake). BMI was calculated as body weight (kilograms) divided by the square of body height (metres). Menstrual cycle and the amount of menstrual flow during the preceding 12 months were also self-reported in the lifestyle questionnaire. With regard to menstrual cycle, the 'regular' category included the number of subjects who replied 'always regular' and 'almost always regular'; 'irregular' included those replying 'half-regular and half-irregular'; and 'infrequently or none' included 'mostly irregular', 'almost none' and 'none'. For amount of menstrual flow, the 'light' category included 'light flow'; 'average' included 'average flow' and 'bleeding with mucus'; and 'heavy' included 'heavy flow' and 'bleeding with clots'. Physical activity was computed as average MET-h/d (where MET = metabolic equivalent)[44] on the basis of the frequency and duration of five different activities (sleeping, high- and moderate-intensity activities, walking and sedentary activities) over the preceding month, as reported in the lifestyle questionnaire[45].

Statistical analysis

Subjects for analysis were identified as described below. In total, 466 women aged 18–25 years enrolling in 2006 and 677 enrolling in 2007 underwent peripheral blood examination. Subjects were excluded from the study if they had missing covariate information (*n* 29); extremely low or high daily energy intake (≤4184 or ≥14 644 kJ (≤1000 or ≥3500 kcal); *n* 31); were using Fe supplements (*n* 50; two subjects using Fe preparations as therapy for anaemia were included as patients with Fe deficiency anaemia); had asthma (allergic), thyroid disease, diabetes mellitus, renal disease or gastrointestinal disease (*n* 34); or showed both decreased values for Hb and normal or increased values for ferritin (*n* 11). Of these last eleven subjects, we assumed normal body Fe status in eight, mild Fe deficiency anaemia in one, Fe deficiency anaemia under Fe supplementation in one, and a haematological disorder other than Fe deficiency anaemia in one. As some subjects were in more than one exclusion category, the final analysis sample comprised 1019 women.

The associations between Fe deficiency and a number of dietary variables, lifestyle variables and health condition were examined. These included twenty-nine dietary variables, i.e. intakes of energy (kJ/d), sixteen nutrients (protein, carbohydrate, fat, total dietary fibre, Ca, total Fe, haem Fe, non-haem Fe, bioavailable Fe (three values for each body Fe reserve), phytate, vitamin A, vitamin C, vitamin D, α-tocopherol, vitamin B_{12} and folic acid), ten food groups (meat, fish, cereals, dairy products, green vegetables, other vegetables, pulses, potatoes, fruits and eggs), black tea and coffee; three lifestyle variables (current smoking status (yes; no), alcohol drinking status (non-drinker; drinker 1; drinker 2) and physical activity (divided into tertiles)); and BMI (<18·5 kg/m^2; ≥18·5 and <25 kg/m^2; ≥25 kg/m^2), menstrual cycle (regular; irregular; infrequent or none) and amount of menstrual flow (light; average; heavy). Dietary variables were classified by quintile and analysed. In addition, survey year (2006 or 2007), residential block and size of residential area were included as potential confounding factors in the model.

We calculated both crude and multivariate-adjusted odds ratios and 95 % confidence intervals for Fe deficiency for each category of included variables using three logistic regression models. In model 1, OR were adjusted for survey year, residential block, size of residential area, current smoking status, alcohol drinking status, physical activity, energy intake, BMI, menstrual cycle and Fe intake. In model 2, they were adjusted for the same factors as in model 1, including amount of menstrual flow instead of menstrual cycle. In model 3, they were adjusted for the same factors as in model 1 and also amount of menstrual flow. Physical activity, energy intake and BMI were used as continuous variables when they were added as covariates in the models. As results for the crude and multivariate analyses were similar for all variables analysed, we present here only those derived from the multivariate models. Trends of association were examined using a logistic regression model which assigned scores to the level of the independent variable.

All statistical analysis was performed using the SAS statistical software package version 9·1 (SAS Institute Inc., Cary, NC, USA). A two-sided P value of <0·05 was considered statistically significant.

Results

Subject characteristics are shown in Table 2. Mean age, total energy and total Fe intake were 19·6 years, 7364 kJ/d (1760 kcal/d) and 3·7 mg/4184 kJ, respectively. Mean estimated bioavailable Fe for each body Fe reserve was 0·067 mg/4184 kJ (supposed body Fe reserve = 500 mg), 0·092 mg/4184 kJ (250 mg) and 0·140 mg/4184 kJ (0 mg). A total of 179 (17·6 %) of 1019 women were classified as having depleted Fe stores and seventy-one (7·0 %) as having Fe deficiency anaemia, giving 250 (24·5 %) women categorized with Fe deficiency.

Table 3 shows the multivariate-adjusted odds ratios and 95 % confidence intervals for Fe deficiency by quintiles of dietary factors. Intakes of total Fe, haem Fe, non-haem Fe and bioavailable Fe were not significantly associated with Fe deficiency, nor was any association observed for any other dietary factor. Since results for the three multivariate models described in the statistical analysis section were similar for all variables analysed, we present only those derived from model 3 (full model), including both menstrual cycle and amount of menstrual flow, in Table 3.

Table 4 shows the multivariate-adjusted odds ratios and 95 % confidence intervals for Fe deficiency in each category of selected lifestyle factors and health condition. Infrequent menstrual cycles was associated with a decreasing prevalence of Fe deficiency. In comparison with women categorized as having regular menstrual cycles, the multivariate-adjusted OR (95 % CI) for women categorized with infrequent or no menstrual cycles was 0·58 (0·34, 1·00) using model 1. On the other hand, heavy menstrual flow was associated with an increasing prevalence of Fe deficiency. In comparison with women categorized with average flow, the multivariate-adjusted OR (95 % CI) for women in the heavy menstrual flow category was 1·83 (1·35, 2·48) using model 2 and 1·85 (1·36, 2·51) using model 3. Correspondingly, women with a lighter flow showed a significantly lower prevalence of Fe deficiency in comparison with those with an average flow. No other lifestyle factors or health conditions were associated with the prevalence of Fe deficiency. These results were not altered if any value for bioavailable Fe intake was included in the model in place of total Fe intake.

Table 2 Characteristics of the subjects: female Japanese dietetic students (*n* 1019) aged 18–25 years

Variable	Mean or *n*	SD or %
Age (years)	19·6	1·1
Body height (cm)	158·3	5·5
Body weight (kg)	53·6	7·8
BMI (kg/m^2)	21·4	2·8
Survey year		
2006	417	40·9
2007	602	59·1
Residential block		
North (Hokkaido, Kanto and Tohoku)	592	58·1
Central (Tokai, Hokuriku and Kinki)	232	22·8
South (Kyushu and Chugoku)	195	19·1
Size of residential area		
City with population ≥1 million	163	16·0
City with population <1 million	791	77·6
Town or village	65	6·4
Current smoking status		
No	995	97·6
Yes	24	2·4
Alcohol drinking status		
No	596	58·5
Yes, <1 % of energy	247	24·2
Yes, ≥1 % of energy	176	17·3
Physical activity (MET-h/d)	33·9	3·0
Menstrual cycle		
Regular	766	75·2
Irregular	148	14·5
Infrequent or none	105	10·3
Amount of menstrual flow		
Light	68	6·7
Average	638	62·6
Heavy	313	30·7
Blood examination		
Hg (g/dl)	13·4	1·0
Serum Fe (μg/dl)	96·7	41·0
Serum ferritin (ng/ml)	28·2	22·8
Body Fe status		
Normal	769	75·5
Fe deficiency	250	24·5
Depleted Fe stores	179	17·6
Fe deficiency anaemia	71	7·0
Dietary intake		
Total energy (kJ/d)	7364	1715
Total energy (kcal/d)	1760	410
Nutrient intake		
Total Fe (mg/4184 kJ)	3·7	0·8
Haem Fe (mg/4184 kJ)	0·24	0·12
Non-haem Fe (mg/4184 kJ)	3·4	0·8
Bioavailable Fe (mg/4184 kJ)		
Body Fe reserve = 500 mg	0·067	0·026
Body Fe reserve = 250 mg	0·092	0·035
Body Fe reserve = 0 mg	0·14	0·05
Phytate (mg/4184 kJ)	341·6	166·6
Vitamin C (mg/4184 kJ)	47·3	21·6
Ca (mg/4184 kJ)	283	95·4
Food group intake		
Meat (g/4184 kJ)	33·6	16·2
Fish (g/4184 kJ)	28·4	15·2
Cereal (g/4184 kJ)	222	57·5
Dairy products (g/4184 kJ)	83·0	71·7

MET, metabolic equivalent.

Discussion

In the present study, we found no association between Fe deficiency and a wide range of dietary variables. In contrast, Fe deficiency was associated with menstrual condition, with infrequent menstrual cycles associated with a decreasing prevalence of Fe deficiency while heavy menstrual flow was associated with an increasing prevalence.

Overall prevalence of Fe deficiency in the study was 24·5 % (depleted Fe stores, 17·6 %; Fe deficiency anaemia, 7·0 %). Given the prevalence ratios in a previous study in Japanese women aged 11–90 years of 41·4 % for depleted

Table 3 Multivariate-adjusted odds ratios and 95 % confidence intervals for iron deficiency by quintile of intake of energy, nutrients and food groups among 1019 Japanese women aged 18–25 years

	Intake				
	Median	Range	*n* with/without Fe deficiency	Adjusted OR*	95 % CI
Energy intake (kJ/d)					
Q1 (Low)	5343	4201–5895	47/156	1·00	
Q2	6326	5899–6728	55/149	1·36	0·86, 2·17
Q3	7155	6728–7577	53/151	1·38	0·86, 2·21
Q4	8134	7581–8644	40/164	0·91	0·55, 1·50
Q5 (High)	9606	8648–14 56	55/149	1·47	0·91, 2·37
P for trend				0·48	
Nutrient intake					
Total Fe (mg/4184 kJ)					
Q1	2·8	1·8–3·1	54/149	1·00	
Q2	3·3	3·1–3·4	47/157	0·80	0·50, 1·27
Q3	3·6	3·4–3·8	52/152	0·95	0·60, 1·51
Q4	4·0	3·8–4·3	49/155	0·86	0·54, 1·38
Q5	4·7	4·3–8·3	48/156	0·86	0·54, 1·38
P for trend				0·68	
Haem Fe (mg/4184 kJ)					
Q1	0·12	0·03–0·15	48/155	1·00	
Q2	0·18	0·15–0·20	53/151	1·20	0·75, 1·90
Q3	0·23	0·20–0·25	49/155	0·99	0·62, 1·58
Q4	0·28	0·25–0·32	50/154	1·10	0·69, 1·77
Q5	0·38	0·32–1·94	50/154	0·99	0·62, 1·60
P for trend				0·86	
Non–haem Fe (mg/4184 kJ)					
Q1	2·6	1·7–2·8	55/148	1·00	
Q2	3·0	2·8–3·2	49/155	0·86	0·54, 1·36
Q3	3·4	3·2–3·6	47/157	0·82	0·51, 1·30
Q4	3·8	3·6–4·0	55/149	1·04	0·66, 1·65
Q5	4·4	4·0–6·8	44/160	0·77	0·48, 1·23
P for trend				0·54	
Bioavailable Fe (mg/4184 kJ)	(BIR = 500 mg)				
Q1	0·043	0·027–0·049	52/151	1·00	
Q2	0·053	0·049–0·056	49/155	0·90	0·57, 1·44
Q3	0·060	0·056–0·065	57/157	0·87	0·55, 1·39
Q4	0·071	0·065–0·080	49/155	0·90	0·56, 1·43
Q5	0·101	0·080–0·276	53/151	0·97	0·60, 1·55
P for trend				0·88	
Bioavailable Fe (mg/4184 kJ)	(BIR = 250 mg)				
Q1	0·060	0·038–0·067	52/151	1·00	
Q2	0·072	0·067–0·077	50/154	0·93	0·58, 1·47
Q3	0·082	0·078–0·088	46/158	0·86	0·54, 1·38
Q4	0·097	0·088–0·109	51/153	0·96	0·60, 1·53
Q5	0·139	0·109–0·350	51/153	0·91	0·56, 1·47
P for trend				0·78	
Bioavailable Fe (mg/4184 kJ)	(BIR = 0 mg)				
Q1	0·092	0·058–0·102	52/151	1·00	
Q2	0·109	0·102–0·115	50/154	0·92	0·58, 1·46
Q3	0·122	0·116–0·130	42/162	0·78	0·49, 1·27
Q4	0·141	0·130–0·160	53/151	1·00	0·63, 1·59
Q5	0·208	0·160–0·471	53/151	0·96	0·59, 1·56
P for trend				0·99	
Phytate (mg/4184 kJ)					
Q1	183·2	84·6–212·6	53/150	1·00	
Q2	239·4	212·9–269·3	52/152	0·95	0·60, 1·50
Q3	301·8	269·3–332·5	46/158	0·86	0·53, 1·39
Q4	372·7	332·8–438·5	51/153	0·93	0·57, 1·51
Q5	562·2	439·2–1368·8	48/156	0·86	0·51, 1·47
P for trend				0·62	
Vitamin C (mg/4184 kJ)					
Q1	25·4	6·9–30·8	53/150	1·00	
Q2	35·3	30·8–39·0	49/155	0·84	0·53, 1·34
Q3	43·2	39·1–48·2	44/160	0·79	0·48, 1·28
Q4	53·0	48·2–60·8	67/137	1·39	0·85, 2·27
Q5	75·2	60·8–202·0	37/167	0·61	0·35, 1·05
P for trend				0·46	
Ca (mg/4184 kJ)					
Q1	175	104–202	54/149	1·00	
Q2	224	202–248	49/155	0·90	0·56, 1·46

Table 3 *Continued*

	Intake		*n* with/without Fe deficiency	Adjusted OR*	95 % CI
	Median	Range			
Q3	268	248–290	57/147	1·20	0·74, 1·94
Q4	318	290–352	45/159	0·88	0·53, 1·47
Q5	414	352–699	45/159	0·89	0·53, 1·48
P for trend				0·67	
Food group intake					
Meat (g/4184 kJ)					
Q1	16·0	3·4–20·1	52/151	1·00	
Q2	23·7	20·2–27·3	54/150	1·03	0·65, 1·62
Q3	30·9	27·3–35·2	48/156	0·77	0·48, 1·23
Q4	40·0	35·2–44·9	50/154	0·90	0·56, 1·43
Q5	54·0	45·0–135·0	46/158	0·73	0·45, 1·18
P for trend				0·17	
Fish (g/4184 kJ)					
Q1	11·6	0·0–15·8	50/153	1·00	
Q2	19·8	15·8–22·9	55/149	1·20	0·76, 1·91
Q3	25·8	22·9–29·8	44/160	0·89	0·55, 1·44
Q4	33·7	29·8–38·7	51/153	1·12	0·70, 1·81
Q5	48·0	38·7–111·0	50/154	1·02	0·62, 1·67
P for trend				0·94	
Cereals (g/4184 kJ)					
Q1	152	41–174	49/154	1·00	
Q2	189	174–205	45/159	0·89	0·55, 1·44
Q3	221	205–234	47/157	0·91	0·56, 1·48
Q4	250	234–268	57/147	1·16	0·71, 1·89
Q5	298	268–425	52/152	0·90	0·53, 1·52
P for trend				0·92	
Dairy products (g/4184 kJ)					
Q1	12·6	0–21·6	56/147	1·00	
Q2	36·4	21·7–49·5	49/155	0·83	0·53, 1·31
Q3	65·8	49·9–82·4	44/160	0·76	0·48, 1·22
Q4	102·0	82·5–125·0	51/153	0·97	0·61, 1·54
Q5	182·0	125·0–367·0	50/154	0·92	0·58, 1·47
P for trend				0·98	

Q, quintile. BIR, body Fe reserve.
*Adjusted OR: adjusted for survey year (2006 or 2007), residential block (north, Hokkaido, Kanto and Tohoku; central, Tokai, Hokuriku and Kinki; south, Kyushu and Chugoku), size of residential area (city with population ⩾1 million; city with population <1 million; town or village), current smoking status, alcohol drinking status, physical activity (total MET-h/d, continuous; where MET = metabolic equivalent), energy intake (kJ/d, continuous), BMI (kg/m^2, continuous), menstrual cycle, amount of menstrual flow and Fe intake (mg/4184 kJ, quintiles). Nutrients and food groups other than total Fe were substituted singly.
Nutrients and food groups that were analysed but found not to be related with Fe deficiency were total Fe, haem Fe, non-haem Fe, bioavailable Fe, phytate, vitamin C, Ca, protein, carbohydrate, fat, total dietary fibre, vitamin A, vitamin D, α-tocopherol, vitamin B_{12}, folic acid, meat, fish, cereals, dairy products, green vegetables, other vegetables, pulses, potatoes, nuts, fruits, eggs, black tea and coffee.

Fe stores and 8·5 % for Fe deficiency anaemia(3), our present ratios are relatively low. However, these results should be interpreted carefully, as all subjects were volunteer dietetic students who may have led a relatively healthy lifestyle. On the other hand, mean Fe intake among our subjects was a relatively low, 3·70 mg/4184 kJ with energy adjustment or 6·55 mg/d without. The lower mean Fe intake in Japan than in other developed countries(19–22) is likely attributed to the different dietary habits of most Japanese, with greater consumption of rice and fish and lower consumption of meat(23). This difference in Japanese dietary habits also likely influenced bioavailable Fe levels in our study.

Dietary factors known to enhance Fe absorption are ascorbic acid (vitamin C), animal tissues (such as meat, fish and poultry), organic acids (such as citric acid and lactic acid), fermented soya products, cysteine-containing peptides(2) and vitamin A(46). When present in sufficient quantity, ascorbic acid has been reported to enhance non-haem Fe absorption in a dose-dependent manner, owing to its ability to overcome the inhibitory effect of phytate(47). Animal tissues, especially red meat such as beef, pork and lamb, not only enhance Fe absorption, but are also excellent sources of highly bioavailable haem Fe(48). In contrast, phytate, polyphenols, Ca, dairy products, soya proteins and dietary fibres are known to inhibit non-haem Fe absorption(2,9). We estimated phytate intake values in the present study and found them to be compatible with those previously reported(37,39). Nevertheless, a food composition table describing phytate content in Japanese food is not available, and further studies are needed to confirm phytate intake in the Japanese population. Phytate intake is also essential to the estimation of bioavailable Fe intake, and measurement of phytate content in Japanese food is therefore also necessary to clarify bioavailable Fe intake in Japan.

To estimate bioavailable Fe intake, we used the algorithms developed by Bhargava *et al.*(37) because these

Table 4 Multivariate-adjusted odds ratios and 95 % confidence intervals for iron deficiency in relation to selected lifestyle factors and health conditions among 1019 Japanese women aged 18–25 years

	Value		n with/without Fe deficiency	Model 1*		Model 2†		Model 3‡	
	Median	Range		OR	95 % CI	OR	95 % CI	OR	95 % CI
Current smoking status									
No			241/754	1·00		1·00		1·00	
Yes			9/15	1·68	0·69, 4·07	1·47	0·60, 3·59	1·41	0·57, 3·44
P				0·25		0·40		0·46	
Alcohol drinking status									
No			149/447	1·00		1·00		1·00	
Yes, <1 % of energy			60/187	0·94	0·66, 1·33	0·95	0·67, 1·36	0·94	0·66, 1·34
Yes, ≥1 % of energy			41/135	0·85	0·56, 1·29	0·84	0·55, 1·28	0·84	0·55, 1·29
P for trend§				0·43		0·42		0·42	
Physical activity‖									
Low	32·0	29·3–32·6	82/255	1·00		1·00		1·00	
Middle	33·2	32·6–33·9	86/256	1·11	0·77, 1·58	1·11	0·77, 1·59	1·12	0·78, 1·61
High	35·3	33·9–68·6	82/258	1·05	0·73, 1·51	1·03	0·71, 1·50	1·05	0·72, 1·51
P for trend				0·79		0·86		0·82	
Menstrual cycle									
Regular			199/567	1·00		–		1·00	
Irregular			33/115	0·84	0·55, 1·28	–		0·88	0·58, 1·36
Infrequent or none			18/87	0·58	0·34, 1·00	–		0·69	0·39, 1·22
P for trend				0·04				0·18	
Amount of menstrual flow									
Light			5/63	–		0·28	0·11, 0·71	0·32	0·12, 0·82
Average			139/499	–		1·00		1·00	
Heavy			106/207	–		1·83	1·35, 2·48	1·85	1·36, 2·51
P for trend						<0·0001		<0·0001	
BMI (kg/m^2)¶									
<18·5			22/89	0·71	0·43, 1·17	0·75	0·45, 1·25	0·76	0·45, 1·25
≥18·5, <25			212/608	1·00		1·00		1·00	
≥25			16/72	0·59	0·33, 1·04	0·57	0·32, 1·01	0·55	0·31, 0·99
P for trend				0·77		0·56		0·52	

*Model 1: adjusted for survey year (2006 or 2007), residential block (north, Hokkaido, Kanto and Tohoku; central, Tokai, Hokuriku and Kinki; south, (Kyushu and Chugoku), size of residential area (city with population ≥1 million; city with population <1 million; town or village), current smoking status, alcohol drinking status, physical activity (total MET-h/d, continuous; where MET = metabolic equivalent), energy intake (kJ/d, continuous), BMI (kg/m^2, continuous), menstrual cycle and total Fe intake (mg/4184 kJ, quintiles).
†Model 2: adjusted for the same factors as model 1, including amount of menstrual flow instead of menstrual cycle.
‡Model 3: adjusted for the same factors as model 1 and amount of menstrual flow.
§Trend of association was examined by a logistic regression model assigning scores to the levels of the independent variable.
‖Physical activity was divided into three groups by tertiles, and odds ratios were calculated by using groups of physical activity as a categorical variable in the models.
¶BMI was divided into three groups at values of 18·5 and 25 kg/m^2, and odds ratios were calculated by using groups by BMI as a categorical variable in the models.

algorithms were established for Bangladeshi subjects who mainly consume rice and do not eat so much animal products. Also, the algorithms were thought to be suitable for our available data because we did not have enough information about polyphenols and tea except black tea, which is needed to use the Hallberg or Tseng algorithms.

We examined all of the dietary factors known to affect Fe metabolism except organic acids, fermented soya products and cysteine-containing peptides. However, results showed no significant association between body Fe status and any dietary factor including total Fe, haem Fe, non-haem Fe and bioavailable Fe. Although our sample size was relatively small and subject characteristics were relatively uniform, the range of Fe intake of 2·50 to 20·01 mg/d suggested a sufficient dispersion of Fe intake.

With regard to the influence of menstruation, results suggested the presence of a dose–response relationship between the amount of menstrual flow and the prevalence of Fe deficiency, albeit that assessment of menstruation was based strictly on unguided self-reporting. These results are consistent with those of previous studies[14,49] and clearly are plausible. Menstrual loss of Fe is the main source of variation in the Fe requirements of non-pregnant, menstruating women and higher menstrual blood loss is associated with a higher prevalence of Fe deficiency[14,15]. Furthermore, several studies have reported a significant inverse correlation between Fe stores and the duration of menstruation[49–51]. In addition, a number of studies in European women have shown a skewed distribution in menstrual blood losses[49,52–54]; while median menstrual loss was about 30 ml, equivalent to a daily Fe loss of 0·45 mg, 25 % had a loss exceeding 0·85 mg/d and 5 % had a loss exceeding 1·75 mg/d. It is suggested that a fraction of women have Fe requirements substantially above mean values.

It might be interesting to explore the relationship between hormonal contraceptive use and Fe deficiency, because usage of hormonal contraceptives clearly affects menstruation. However, it was reported that only 1·1 % of Japanese women of reproductive age (15–49 years) are using them[55]. Therefore we did not include the contraceptive method in our model.

Other lifestyle factors, including current smoking status, alcohol drinking status and physical activity level, as well as BMI, were not associated with the prevalence of Fe deficiency. However, several important factors not considered in the study are likely relevant. For example, body Fe status may be affected by several genetic variations. Although no genetic syndrome in man causing isolated Fe deficiency has been described, differences in response to Fe-deficient diets in genetically distinct mice have been observed[56]. Several case reports have described familial Fe deficiency anaemia that is unresponsive to oral Fe therapy and incompletely responsive to parenteral Fe therapy[57–59]. Further, mutation of the hereditary haemochromatosis (HEF) gene is well-known as the most common cause of hereditary haemochromatosis[60,61].

Several limitations of the present study warrant mention. First, although Fe deficiency has been widely studied, definitions of Fe deficiency, depleted Fe stores and Fe deficiency anaemia have not been properly established. We based our diagnosis of Fe deficiency on previously reported values for Hb concentration and serum ferritin level[42,43]. Nevertheless, concerns about the use of serum ferritin level as an index of body Fe status have been expressed; among them, serum ferritin escalation can coincide with minor infection that is not related to levels of Fe stores[62] and day-to-day variability may be subject to measurement imprecision[63,64].

Given these concerns, several studies have used transferrin saturation (the value of serum Fe/total Fe binding capacity × 100 (%)) in combination with Hb concentration and serum ferritin level as an index of Fe deficiency[42,43,65]. Generally, Fe deficiency is diagnosed when transferrin saturation is below 16%. However, transferrin saturation similarly decreases with mild or transient infection and shows wide diurnal variation in normal individuals[42]. Given that our present subjects were young and assumed to be generally healthy, we considered that the presence of infection would be less likely. To simplify diagnostic criteria, we therefore restricted the indices to serum ferritin level and Hb concentration.

Second, although the DHQ used has been validated with respect to commonly studied nutritional factors, including Fe, as described above, the validity of several factors used in the present study, including bioavailable Fe and phytate, is unknown. The results should thus be interpreted with caution. Additionally, it is true that misreporting is one of the major limitations of any self-reported dietary assessment method. However, the reporting accuracy of the subjects was thought to be acceptable according to a previous study[66] which included the same subjects as the present study. In the present study, reporting accuracy was calculated as the ratio of reported dietary intake obtained from the DHQ to estimated dietary intake obtained from respective biological markers, and most of the calculated values were in the range of 0·9–1·2. For the analysis of our study, nutrient and food intakes were energy-adjusted to avoid the effect of misreporting.

Finally, the present study was a cross-sectional study and thus susceptible to the possibility of reverse causality. Namely, subjects who were conscious of their own Fe deficiency might have increased their consumption of Fe-rich foods. We therefore excluded from analysis those subjects taking Fe supplements, but included two subjects using Fe preparations as therapy for anaemia as patients with Fe deficiency anaemia without regard to Hb or serum ferritin values.

In conclusion, we found no association between any dietary habit, including Fe intake, and Fe deficiency. In contrast, the only variables showing a statistically significant association with the prevalence of Fe deficiency were related with menstrual condition, i.e. menstrual cycle regularity and amount of menstrual flow.

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References

1. Looker AC, Dallman PR, Carroll MD, Gunter EW & Johnson CL (1997) Prevalence of iron deficiency in the United States. *JAMA* **277**, 973–976.
2. Heath A-LM & Fairweather-Tait SJ (2002) Clinical implications of changes in the modern diet: iron intake, absorption and status. *Best Pract Res Clin Haematol* **15**, 225–241.
3. Uchida T, Kawachi Y, Sakamoto Y, Igaki T, Ogasawara N, Kariyone S, Matsuda S, Tanaka T, Kimura H & Kokubun K (1992) Prevalence and pathogenesis of iron deficiency in Japanese women (1981–1991). *Rinsho Ketsueki* **33**, 1661–1665.
4. Sanstead HH (2000) Causes of iron and zinc deficiencies and their effects on brain. *J Nutr* **130**, 347S–349S.
5. Scholz B, Gross R, Schultink W & Sastroamidjojo S (1997) Anaemia is associated with reduced productivity of women