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Monetary cost of dietary energy is negatively associated with BMI and waist circumference, but not with other metabolic risk factors, in young Japanese women

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Abstract

Objective: Little is known about the relationship of dietary cost to health status. The present cross-sectional study examined the association between the monetary cost of dietary energy (Japanese yen/4184 kJ) and several metabolic risk factors.
Design: Monetary cost of dietary energy was estimated based on dietary intake assessed by a self-administered diet history questionnaire and retail food prices. Body height and weight, from which BMI was derived, waist circumference and blood pressure were measured and fasting blood samples were collected for biochemical measurements.
Setting: A total of fifteen universities and colleges in Japan.
Subjects: A total of 1136 female Japanese dietetic students aged 18–22 years.
Results: After adjustment for potential confounding factors, monetary cost of dietary energy was significantly and negatively associated with BMI (*P* for trend = 0·0024). Monetary cost of dietary energy also showed a significant and negative association with waist circumference independently of potential confounding factors, including BMI (*P* for trend = 0·0003). No significant associations were observed for other metabolic risk factors examined (*P* for trend = 0·10–0·88).
Conclusions: The monetary cost of dietary energy was independently and negatively associated with both BMI and waist circumference, but not other metabolic risk factors, in a group of young Japanese women.

Keywords
Monetary cost
Diet
Energy intake
Body mass index
Waist circumference
Japanese women
Epidemiology

While several studies have shown that monetary diet cost is associated with diet quality[1,2], little is known about the relationship of dietary cost to health status. A Spanish study reported an association between higher costs of healthy dietary patterns and lower BMI[3]. The monetary cost of dietary energy was negatively associated with BMI in Japanese women[4]. However, the possible association between dietary cost and other metabolic risk factors has not been investigated. The relationship of monetary cost of dietary energy to health status is an important topic for public health nutrition, because if an independent and direct association actually exists between the cost of dietary energy and health, this may imply that public health interventions aimed at decreasing the energy cost of healthy diets could have a potential to improve population health.

Here, we investigated the association of monetary cost of dietary energy with several metabolic risk factors, including BMI, waist circumference, systolic and diastolic blood pressure, total, HDL and LDL cholesterol, fasting TAG and glucose, and glycated haemoglobin.

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Methods

Subjects

The present cross-sectional study was conducted from February to March 2006 and from January to March 2007 among female dietetic students from fifteen institutions in Japan (*n* 1176). The study protocol was approved by the Ethics Committee of the National Institute of Health and Nutrition; written informed consent was obtained from each subject and also from a parent for subjects aged <20 years. For analysis, women aged 18–22 years were selected (*n* 1154). We then excluded women not completing survey questionnaires (*n* 1), those with extremely low or high reported energy intakes (<2092 or >16 736 kJ/d; *n* 2), those currently receiving dietary counselling from a doctor or dietitian (*n* 13) and those with previously diagnosed diabetes, hypertension or CVD (*n* 1). In each analysis, those with missing values for the outcome variable were also excluded (*n* 2 to *n* 34). Final sample size ranged from 1088 to 1136 depending on outcome.

Monetary cost of dietary energy

Dietary habits during the preceding month were assessed using a self-administered, comprehensive, diet history questionnaire (DHQ)[5–7]. Detailed descriptions of the DHQ on its structure, methods used for calculating dietary intake and validity regarding commonly studied nutritional factors have been published elsewhere[5–7]. Briefly, 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 116 selected food and non-alcoholic beverage items; (v) dietary supplements; (vi) consumption frequency and semi-quantitative portion size of nineteen cereals (rice, bread and noodles), soup consumed with noodles and miso (fermented soyabean paste) soup; and (vii) open-ended items for foods consumed regularly (once per week or more) but not appearing in the DHQ[5]. The food and beverage items were selected as foods commonly consumed in Japan, mainly from a food list used in the National Nutrition Survey of Japan, and standard portion sizes were derived mainly from several recipe books for Japanese dishes[5]. Estimates of daily intake for a total of 148 food and beverage items (including five seasonings; g/d) and energy (kJ/d), energy-adjusted intake of protein (percentage of energy), fat (percentage of energy) and dietary fibre (g/4184 kJ) were calculated using an *ad hoc* computer algorithm for the DHQ[5], based on the *Standard Tables of Food Composition in Japan*[8]. Dietary energy density (kJ/g) was calculated based on foods only (excluding all caloric and non-caloric beverages including water)[9]. Information on dietary supplements and data from the open-ended questionnaire items were not used in the calculation of dietary intake[5].

Monetary cost of the habitual diet (Japanese yen/d) was calculated by multiplying the amount of each food estimated from the DHQ (g/d) by the estimated price of the food (Japanese yen/g) and summing the products (1 Japanese yen = 0·006 € = 0·008 $US in June 2007), using a total of 135 food items after excluding alcoholic beverages (six items), non-caloric beverages (four items) and water (three items)[10]. The procedure for estimating diet costs was based on the assumption that all foods were purchased and then prepared and consumed at home[11,12]. The price of each food was determined mainly from the National Retail Price Survey 2004 (122 items)[13]. For foods whose price were not published in the survey (thirteen items), prices were taken from the websites of nationally distributed supermarket (Seiyu, Tokyo, Japan) and fast-food restaurant (McDonalds, Tokyo, Japan and Mister Donut, Tokyo, Japan) chains. Costs of combined foods such as pizza were calculated using prices of frozen equivalents[3]. Monetary cost of dietary energy (Japanese yen/4184 kJ) was calculated by dividing the estimated daily cost of the diet (Japanese yen/d) by the daily energy intake (kJ/d) and multiplying by 4184. A detailed description of the cost calculation method as well as monetary cost of each food has been published elsewhere[4].

Metabolic risk factors

Body height was measured to the nearest 0·1 cm with the subject standing without shoes. Body weight in light indoor clothes was measured to the nearest 0·1 kg. BMI was calculated as body weight divided by the square of body height (kg/m^2). Waist circumference was measured at the level of the umbilicus to the nearest 0·1 cm. The measurement was taken at the end of a normal expiration while the subject was standing erect with her arms at her side and feet together. Systolic and diastolic blood pressure were measured on the left arm with an automatic device (model HEM-770A; Omron Health Care, Kyoto, Japan) after the subject had been sitting quietly for ≥3 min. A second measurement was carried out about 1 min after the first, and the mean value of the two was used.

Peripheral blood samples were obtained from subjects after an overnight fast. Blood was collected in evacuated tubes containing no additives, allowed to clot, and centrifuged at 3000 ***g*** for 10 min at room temperature to separate the serum. Blood samples for glycated haemoglobin measurements were also collected in evacuated tubes containing no additives. Blood samples were transported at −20°C by car or aeroplane to ensure delivery to a laboratory in Tokyo, Japan (SRL, Inc. in the 2006 survey and Mitsubishi Kagaku Bio-Clinical Laboratories, Inc. in the 2007 survey). The biochemical variables listed below were assayed at the laboratory within 1–2 d of collection to avoid significant degradation. Serum total, LDL and HDL cholesterol, TAG and glucose concentrations were measured by enzymatic assay methods. Glycated haemoglobin was measured by latex agglutination–turbidimetric immunoassay. In-house quality-control procedures for all assays were conducted at the respective laboratory.

Other variables

In a lifestyle questionnaire, the subject reported her residential area, which was grouped into one of three regions (residential block: north (Kanto, Hokkaido, and Tohoku), central (Tokai, Hokuriku, and Kinki) or south (Kyushu and Chugoku)). The residential areas were also grouped into three categories according to population size (size of residential area: city with population ≥1 million, city with population <1 million, town or village). The lifestyle questionnaire also assessed living status (living with family, living alone, others), current smoking (yes or no) and whether currently trying to lose weight (yes or no). Rate of eating (slow, medium, fast) was self-reported as part of the DHQ. Physical activity was computed as the average metabolic equivalent-hours per day, 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.

Statistical analysis

All statistical analyses were performed using the SAS statistical software package version 8·2 (SAS Institute Inc., Cary, NC, USA). Linear regression models were constructed (using the PROC GLM procedure) to examine the association between monetary cost of dietary energy and metabolic risk factors. For analysis, subjects were categorized into quintiles according to monetary cost of dietary energy. The mean (and 95 % confidence interval) metabolic risk factor values were calculated by quintiles of monetary cost of dietary energy after multivariate adjustment for potential confounding factors, including residential area, size of residential area, living status, survey year (2006 or 2007; because of the different laboratories used for blood analyses for the 2006 and 2007 surveys, even though there were no differences in the assay methods), current smoking, currently trying to lose weight, rate of eating and physical activity; BMI was additionally added as a confounder in all analyses except for that for BMI itself. This was conducted for investigating independent associations between monetary cost of dietary energy and metabolic risk factors. When a significant association was observed in the above model, further adjustment was done for dietary composition (protein, fat and dietary fibre intake) or dietary energy density. This was conducted for investigating possible causal pathways; dietary composition has been shown to be associated not only with metabolic risk factors[14–16] but also with monetary diet cost[4,12,17], while dietary energy density has similarly been shown to be associated not only with metabolic risk factors[9,18] but also with monetary diet cost[2,4,11]. Linear trends with increasing levels of monetary cost of dietary energy were tested by assigning each participant a median value for the category and modelling this value as a continuous variable. We also calculated the regression coefficient (and 95 % confidence interval) of variation of metabolic risk factors by an increase of monetary cost of dietary energy (100 Japanese yen/4184 kJ) by multiple regression analysis with adjustment for the potential confounding factors indicated above (using the PROC REG procedure). All reported *P* values are two-tailed, and a *P* value of <0·05 was considered significant.

Results

Lifestyle, dietary, anthropomorphic and biochemical characteristics of all subjects (*n* 1136; those included in the analyses of BMI, waist circumference, and systolic and diastolic blood pressure) are shown in Table 1. Mean monetary cost of dietary energy was 444 Japanese yen/4184 kJ, while mean BMI was 21·3 kg/m^2 and mean waist circumference was 72·9 cm. These characteristics of all subjects according to quintile of monetary cost of dietary energy are also presented in Table 1. In the higher quintiles of monetary cost of dietary energy, there were more subjects living with the family and fewer subjects living alone. Monetary cost of dietary energy was associated positively with intake of protein, fat and dietary fibre and negatively with dietary energy density. There was also a negative association of monetary cost of dietary energy with BMI and waist circumference. According to the quintile of monetary cost of dietary energy, similar patterns were observed for potential confounding factors among those subjects included in the analyses of cholesterol (total, HDL and LDL) and glycated haemoglobin (*n* 1121), fasting TAG (*n* 1088) and fasting glucose (*n* 1089; data not shown).

Table 2 shows the independent association of monetary cost of dietary energy with metabolic risk factors. Generally, similar results were observed when monetary cost of dietary energy was treated as a categorical variable (quintile) and as a continuous variable. After adjustment for potential confounding factors, monetary cost of dietary energy was negatively associated with BMI (model 1). In further investigation of possible causal pathways, this inverse association disappeared after additional adjustment for dietary composition (model 2), but remained after that for dietary energy density (model 3). Monetary cost of dietary energy also showed a negative association with waist circumference independently of potential confounding factors (model 1), including BMI (model 4). In further investigation of possible causal pathways, this inverse association remained after additional adjustment for dietary composition (model 5) or dietary energy density (model 6). No independent associations were observed between monetary cost of dietary energy and

Table 1 Subject characteristics according to quintile of monetary cost of dietary energy (n 1136)*: subset of participants in the Japan Dietetic Students' Study for Nutrition and Biomarkers, 2006 and 2007

	All (n 1136)		Quintile of monetary cost of dietary energy: 1 (n 227)		2 (n 227)		3 (n 228)		4 (n 227)		5 (n 227)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P†
Monetary cost of dietary energy (Japanese yen/4184 kJ)‡	444	77	343	30	401	11	440	11	479	13	556	50	<0·0001
	n	%	n	%	n	%	n	%	n	%	n	%	
Residential block													0·15
North (Kanto, Hokkaido and Tohoku)	636	56	125	55	124	55	121	53	138	61	128	56	
Central (Tokai, Hokuriku and Kinki)	275	24	47	21	61	27	56	25	53	23	58	26	
South (Kyushu and Chugoku)	225	20	55	24	42	19	51	22	36	16	41	18	
Size of residential area													0·52
City with population ≥1 million	183	16	30	13	29	13	38	17	42	19	44	19	
City with population <1 million	883	78	189	83	186	82	176	77	168	74	164	72	
Town or village	70	6	8	4	12	5	14	6	17	7	19	8	
Living status													<0·0001
Living with family	683	60	69	30	113	50	147	64	163	72	191	84	
Living alone	405	36	144	36	100	44	77	34	54	24	30	13	
Others	48	4	14	6	14	6	4	2	10	4	6	3	
Survey year													0·002
2006	461	41	83	37	82	36	88	39	94	41	114	50	
2007	675	59	144	63	145	64	140	61	133	59	113	50	
Current smoking													0·29
No	1107	97	217	96	223	98	223	98	223	98	221	97	
Yes	29	3	10	4	4	2	5	2	4	2	6	3	
Currently trying to lose weight													0·65
No	879	77	175	77	176	78	176	77	187	82	165	73	
Yes	257	23	52	23	51	22	52	23	40	18	62	27	
Rate of eating													0·38
Slow	343	30	63	28	71	31	67	29	76	33	66	29	
Medium	344	30	64	28	64	28	80	35	67	30	69	30	
Fast	449	40	100	44	92	41	81	36	84	37	92	41	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Physical activity (total MET-h/d)	33·9	3·1	33·8	3·4	33·7	2·4	34·0	3·4	33·7	2·5	34·4	3·4	0·06
Dietary composition													
Protein (% of energy)	13·5	1·9	11·9	1·5	12·9	1·4	13·4	1·3	14·1	1·4	15·2	1·9	<0·0001
Fat (% of energy)	29·1	5·2	26·2	5·2	28·9	5·0	29·5	4·8	30·1	4·3	31·0	5·1	<0·0001
Dietary fibre (g/4184 kJ)	6·8	2·0	5·6	1·4	6·1	1·4	6·7	1·4	7·2	1·5	8·6	2·5	<0·0001
Dietary energy density (kJ/g)	5·90	0·96	6·49	1·05	6·15	0·92	5·90	0·79	5·65	0·75	5·27	0·88	<0·0001
Metabolic risk factors													
BMI (kg/m^2)	21·3	2·7	21·9	2·8	21·2	2·6	21·4	2·6	21·1	2·4	21·1	3·2	0·001
Waist circumference (cm)	72·9	7·1	75·0	7·8	72·5	6·4	73·0	6·8	72·3	6·4	71·7	7·4	<0·0001
Systolic blood pressure (mmHg)	106·4	10·6	106·3	9·7	106·5	11·2	106·5	10·5	106·9	10·4	105·7	11·2	0·84
Diastolic blood pressure (mmHg)	69·3	8·2	69·5	7·5	69·0	7·9	69·3	8·7	69·5	7·7	69·4	9·0	0·95
Total cholesterol (mg/dl)	188·9	31·8	189·3	32·5	186·8	29·5	187·7	31·4	190·0	33·0	190·5	32·7	0·72
HDL cholesterol (mg/dl)	70·6	12·7	70·9	12·4	70·2	12·1	71·2	13·0	69·4	13·4	71·0	12·7	0·56
LDL cholesterol (mg/dl)	107·0	27·2	108·1	27·6	104·8	26·6	105·2	26·7	109·4	27·9	107·2	27·3	0·34
Fasting TAG (mg/dl)	61·1	28·8	61·9	26·5	64·8	34·7	58·6	25·0	61·6	31·7	58·6	24·6	0·13
Fasting glucose (mg/dl)	84·0	6·4	83·8	5·5	84·3	7·2	83·8	6·5	84·9	6·1	83·5	6·5	0·17
Glycated haemoglobin (%)	4·87	0·26	4·85	0·29	4·87	0·26	4·87	0·23	4·86	0·25	4·88	0·27	0·85

MET, metabolic equivalents.

*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 continuous variables, a linear trend test was used with the median value in each quintile as a continuous variable in linear regression analysis; for categorical variables, a Mantel–Haenszel χ^2 test was used.

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

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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/m²)														
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/m², 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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