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Original Article

Dietary patterns in infancy and their associations with maternal socio-economic and lifestyle factors among 758 Japanese mother–child pairs: the Osaka Maternal and Child Health Study

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Abstract

Dietary habits established in early childhood contribute to lifelong dietary pattern and the development of early risk factors for disease in adulthood. Although a large body of epidemiologic data from Western countries show that the dietary pattern of children is influenced by maternal socio-economic and lifestyle characteristics, information on this topic in non-Western countries is absolutely lacking. The present study identified dietary patterns among infants aged 16–24 months, and then examined the influence of maternal socio-economic and lifestyle characteristics on identified dietary patterns. Subjects were 758 Japanese mother–child pairs. Dietary data of infants were collected from the mothers using a questionnaire. Dietary patterns were extracted from the consumption of 15 foods (times week^{-1}) by cluster analysis. The following two dietary patterns were identified: 'fruits, vegetables and high-protein foods' ($n = 483$) and 'confectionaries and sweetened beverages' ($n = 275$) patterns. After adjustment for all other predictors, maternal educational level, number of infants' siblings and maternal dietary patterns were independently associated with dietary patterns of infants. Infants whose mothers had a higher educational level and the 'rice, fish and vegetables' dietary pattern were less likely to belong to the 'confectionaries and sweetened beverages' pattern, whereas infants whose mothers had a higher number of children and the 'wheat product' dietary pattern were more likely to belong to the 'confectionaries and sweetened beverages' than the 'fruits, vegetables and high-protein foods' pattern. In conclusion, the mother's socio-economic position and dietary patterns were associated with the dietary patterns of infants in the Japanese pairs as observed in the Western populations.

Keywords: dietary patterns, cluster analysis, socio-economic characteristics, infants, mothers.

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Introduction

An optimal diet among pre-school children is particularly important in terms of growth, development, health and future taste preferences. Additionally, dietary habits established in early childhood contribute to lifelong dietary pattern (Mikkilä *et al*. 2005) and the development of early risk factors for chronic diseases in adulthood, such as cardiovascular disease (Ness *et al*. 2005; Mikkilä *et al*. 2007). The acquisition of healthful dietary habits in early childhood and the identification of groups with poor dietary habits as early as possible in life course (such as a previous study conducted by Pryer & Rogers 2009) are therefore important in preventing or delaying the development of chronic disease from the perspective of preventive medicine (Darnton-Hill *et al*. 2004).

In recent years, several study groups in Western countries have examined patterns of child diet from infancy to pre-school age using exploratory statistical methods such as factor analysis and cluster analysis to capture the whole diet in combination rather than the consumption of individual food items or nutrient intakes (North & Emmett 2000; Northstone & Emmett 2005; Robinson *et al*. 2007; Ovaskainen *et al*. 2009; Pryer & Rogers 2009; Ystrom *et al*. 2009; Manios *et al*. 2010; Moreira *et al*. 2010). Furthermore, they have identified the factors that influence the eating patterns of children. These studies have consistently shown that children who had mothers with a higher socio-economic status consumed high quality diets compared with those with a lower status. An increasing number of studies have shown that younger maternal age, shorter duration of education, lower household income, financial difficulties, higher number of children, daily smoking, lower employment status and higher body mass index are risk factors for feeding their children more unhealthy diets and for feeding less healthy diets (North & Emmett 2000; Rogers & Emmett 2003; Northstone & Emmett 2005; Robinson *et al*. 2007; Ovaskainen *et al*. 2009; Pryer & Rogers 2009; Ystrom *et al*. 2009). However, all studies on this topic to date were conducted in Western countries, and we are unaware of any comparable research reported in Asian countries, including Japan, which have different culture-specific dietary habits.

Cluster analysis, which is as popular as factor analysis, is useful in nutritional epidemiologic studies to define dietary pattern because it allows a clear description of existing patterns in the population by providing mean values for food groups within each cluster (Tucker 2010). Therefore, subgroups of the population that have different dietary patterns from the majority may be clearly identified. Furthermore, to our knowledge, the study on the infantile dietary patterns defined by cluster analysis is sparse (Ovaskainen *et al*. 2009; Pryer & Rogers 2009), compared with those by factor analysis or principal component analysis (North & Emmett 2000; Northstone & Emmett 2005; Robinson *et al*. 2007; Ystrom *et al*. 2009).

Here, using data from the Osaka Maternal and Child Health Study (OMCHS) (Miyake *et al*. 2004, 2009), we used cluster analysis to identify dietary patterns in a group of Japanese infants aged 16–24 months and evaluated whether the dietary patterns of infants thereby obtained were associated with maternal socio-economic characteristics and lifestyle factors.

Key messages

- We identified two distinct dietary patterns by cluster analysis among Japanese infants aged 16–24 months. Cluster 1 was characterised by a high intake of staple foods, meat, fish, eggs, vegetables, fruits, yogurt and tea. Cluster 2 was characterised by a high intake of puddings and jellies, chocolate, rice crackers and several kinds of juices.
- We found that maternal educational level had an important influence on dietary patterns of infants.
- Mothers with a higher diet quality were more likely to provide a diet characterised by these foods for their infants, whereas mothers with a lower diet quality were more likely to provide a comparable dietary pattern.

Materials and methods

Study procedure and subjects

The OMCHS is a prospective cohort study that investigates preventive and risk factors for maternal and child health problems such as allergic disorders. Details of the OMCHS have been described elsewhere (Miyake *et al*. 2004, 2009). Briefly, all pregnant women in Neyagawa City, 1 of the 43 municipalities in Osaka Prefecture, were recruited between November 2001 and March 2003. Of 3639 eligible women, 627 (17.2%) agreed to participate in the survey. An additional 375 pregnant women living in other municipalities were also enrolled between December 2001 and November 2003. Finally, a total of 1002 pregnant women at gestation weeks 5–39 gave their fully informed consent in writing and completed the baseline survey. Of these, 867 mother–child pairs participated in the second survey from 2- to 9-month post-partum, of whom 763 pairs participated in the third survey from 16- to 24-month post-partum. After excluding five mother–child pairs with missing information on the variables used in the present study, such as child anthropometric measurements at birth and 18 months ($n = 2$) and maternal body weight at 20 years treated as pre-pregnancy body weight ($n = 4$), the final analysis consisted of 758 mother–child pairs. The protocol of the OMCHS was approved by the ethics committee of Osaka City University School of Medicine.

Measurements

Baseline assessment of the OMCHS was primarily conducted using a set of two self-administered questionnaires on dietary habits and a wide range of lifestyle behaviours (Miyake *et al*. 2004). A self-administered questionnaire was also used in each of the second and third surveys after the birth of infants. The participants mailed these answered questionnaires to the data management centre at the time each survey was conducted, and research technicians completed missing or illogical data by telephone interview.

In the baseline survey during pregnancy, a wide variety of socio-economic and lifestyle variables of mothers were obtained from a self-administered questionnaire designed for this survey (Miyake *et al*. 2004). Assessed items included the distribution of socio-economic and lifestyle factors, including maternal age (<30 or ≥30 years), cigarette smoking (never, former or current), family structure (nuclear or expanded), whether the woman currently had a husband (no or yes), current employment status (unemployment, part-time employment or full-time employment), maternal education [<13 (high school or less), 13–14 (technical or professional school) and ≥15 years (university or more)] and household income (<4 000 000, 4 000 000–5 999 999 or ≥6 000 000 Japanese yen year^{-1}). Other data, such as maternal physical activity level at baseline (low, moderate or high), maternal body weight at 20 years (kg) and maternal dietary intake preceding month in pregnancy, were obtained from a self-administered diet history questionnaire (DHQ) (Sasaki *et al*. 1998a,b, 2000). Maternal body weight at 20 years was used as pre-pregnancy body weight because of a lack of information on maternal body weight just before pregnancy. Pre-pregnancy body mass index (kg m^{-2}) was calculated by dividing the self-reported maternal body weight at 20 years (kg) by the square of self-reported body height (m^2).

For the second survey at 4-month post-partum, a self-administered questionnaire elicited information on the baby's gender, birthweight (g), birth height (cm), date of birth and number of infant's older siblings (0, 1 and ≥2), while that in the third survey at 18-month post-partum included questions on infantile body weight and height at 18 months of age, the infant's current diet, duration of breastfeeding (months), age of introduction of solid foods (months) and time permitted to watch television (TV) or videos (hours day^{-1}). The guideline of weaning for infants in Japan recommends gradual introduction of solid foods from the age of 5 or 6 months (Ministry of Health, Labor, and Welfare of Japan 2007). Age of introduction of solid foods was therefore classified into three categories [<5 months (before recommendation), 5–6 months (adhering to the guideline) and ≥7 months (after recommendation)]; TV or videos viewing was classified into two categories (<2 and ≥2 h day^{-1}) based on the American Academy of

Pediatrics (2001). Information on the infant's current dietary habits during the preceding month was obtained from the mother in terms of the consumption frequency of 21 selected food and beverage items without specification of portion size (Table 1). We included six food items for commercial baby foods (staple foods including rice, porridge, noodles, bread and pancake; meat; fish; vegetables; 100% fruit juice; and sweetened fruit juice) and 15 food items commonly consumed by Japanese infants (staple foods including rice, porridge, noodles, bread and pancakes; meat; fish; eggs; vegetables; fruits; yogurt; pudding and jelly; 100% fresh fruit juice; sweetened fruit juice; other sweetened juice such as Pocari Sweat® (Otsuka Pharmaceutical Co., Ltd., Japan); green tea and oolong tea; chocolate; hard biscuits and soft biscuits; and rice crackers). Eight pre-defined frequency categories ranging from 'less than once per month' to 'two or more times per day' were used. All reported frequency category for each item was converted to a weekly consumption, considering 1 month equal to 4 weeks. For pre-defined frequency categories, the midpoint of each category was assumed as the most likely consumption (i.e. reported consumption of '4–6 times/week' was calculated as '5 times/week').

Statistical analysis

Of the total 21 food items, six baby food items were rarely eaten. More than 90% of infants did not eat baby food products more than once per month during the previous month. Therefore, six baby food items were omitted from the analysis to remove the effect of outliers. Dietary patterns of infants based on the weekly consumption of 15 food groups were generated by *K*-means cluster analysis using the FASTCLUS procedure in SAS (SAS Institute Inc., Cary, NC, USA). Prior to cluster analysis, we standardised frequencies of weekly consumption (times week^{-1}) to a mean of zero and standard deviation of one to remove the extraneous effect of variables with large variances. In the *K*-means cluster algorithm, the investigator needs to select the number of cluster solutions prior to analysis. However, it is difficult to determine the initial cluster seeds because no information was available about the 'true' number of clusters (i.e. dietary patterns) in this data set among Japanese infants. We therefore used a two-step process to determine the most appropriate number of clusters. First, we adopted an *a posteriori* approach, using principal component analysis with the 15 food groups to identify the initial cluster seeds (Villegas *et al*. 2004). From the initial exploratory analysis, we judged that there were two clusters in the present data. Second, we conducted several runs with the number of clusters varied from two to six. The cluster solution was selected by comparing the ratio of between-cluster variance to within-cluster variance divided by the number of clusters (scree-plot). Based on the results of exploratory analysis, scree-plot and the nutritional meaningfulness of clusters, we finally selected the two-cluster solutions as the most appropriate number.

To describe the characteristics of the two clusters of dietary pattern for infants, we calculated subject characteristic means and frequencies for each cluster separately. Furthermore, maternal clusters of dietary pattern in pregnancy were also extracted from the intake of 33 pre-defined food groups from the DHQ by cluster analysis to examine the influence of maternal dietary patterns on those of infants. The method used to identify maternal clusters of dietary pattern and the characteristics of the three clusters thereby identified ('meat and eggs', 'wheat products' and 'rice, fish and vegetables') have been described elsewhere (Okubo *et al*. 2011). Briefly, the 'meat and eggs' cluster was characterised by significantly higher intakes of beef and pork, processed meat, eggs, coffee and cocoa, and dairy products; the 'wheat products' cluster by significantly higher intakes of bread, noodles, confectioneries, fruit and vegetable juice, and soft drinks; and the 'rice, fish and vegetables' cluster by significantly higher intakes of rice, potatoes, pulses, fruit, green and yellow vegetables, white vegetables, pickled vegetables, mushrooms, seaweeds, Japanese and Chinese tea, fish, shellfish, sea products, chicken, miso soup and salt-containing seasonings. The 'rice, fish and vegetables' cluster showed a better nutritional profile with the lowest prevalence of inadequacy for many essential micronutrients, whereas the 'wheat products' cluster showed the opposite characteristic (Okubo *et al*. 2011). Differences in food intake and characteristics of infants between clusters

Table 1. Differences in subject characteristics and the frequency of weekly consumption of foods (times week^{-1}) between dietary patterns identified by cluster analysis among 758 Japanese infants aged 16–24 months: the Osaka Maternal and Child Health Study, Japan

Food group	All		Dietary pattern*				*P*-value†
	($n = 758$)		Cluster 1: Fruits, vegetables and high-protein foods		Cluster 2: Confectionaries and sweetened beverages		
	Mean	SD	($n = 483$)		($n = 275$)		
			Mean	SD	Mean	SD	
Age (months)	19.7	1.1	19.7	1.0	19.8	1.2	0.450
Birthweight (g)	3072	353	3072	350	3072	358	0.994
Birth height (cm)	48.8	1.8	48.8	1.7	48.8	2.0	0.663
Body weight at 18 months (kg)	10.8	3.4	10.8	1.1	10.9	5.4	0.741
Body height at 18 months (cm)	81.6	3.0	81.7	3.0	81.4	3.0	0.244
Sex (%)							
Boy	53		53		52		0.823
Girl	47		47		48		
Season when data collected (%)							
Spring	31		33		288		0.391
Summer	22		21		24		
Fall	20		19		22		
Winter	27		28		26		
Baby foods non-users (%)	19		19		21		0.483
Food intake (times week^{-1})							
Staple foods	17.2	1.8	<u>17.5</u>	0.0	16.7	3.0	–
Meat	5.6	4.1	<u>6.4</u>	4.4	4.3	3.0	–
Fish	4.7	3.2	<u>5.3</u>	3.5	3.5	2.3	–
Eggs	3.4	2.6	<u>3.6</u>	2.7	3.0	2.4	–
Vegetables	13.2	5.8	<u>17.2</u>	1.9	6.4	3.3	–
Fruits	6.3	4.8	<u>7.4</u>	5.1	4.5	3.5	–
Yoghurt	3.2	3.0	<u>3.5</u>	3.0	2.7	2.7	–
Green tea and oolong tea	16.2	4.0	<u>16.6</u>	3.3	15.6	4.8	–
100% fresh fruit juice	3.3	4.5	2.8	3.9	<u>4.1</u>	5.4	–
Sweetened fruit juice	1.8	3.4	1.1	2.1	<u>3.0</u>	4.7	–
Other sweetened juice	1.0	2.7	0.9	2.5	1.1	2.9	–
Puddings and jellies	1.2	2.0	1.1	1.6	<u>1.4</u>	2.4	–
Chocolate	1.0	1.9	0.7	1.3	<u>1.4</u>	2.6	–
Cookies	2.5	2.4	2.5	2.2	2.5	2.6	–
Rice crackers	1.9	2.5	1.7	2.0	<u>2.3</u>	3.0	–

SD, standard deviation. Values are means and standard deviation or percentage. *Cluster names were primarily based on food groups with high intakes. †*P*-value was calculated by Student's *t*-test for continuous variables and the chi-squared test for categorical variables to test differences between dietary patterns. The higher mean values of food intake are underlined.

were tested using Student's *t*-test; and differences in variables expressed as a proportion, such as socio-economic characteristics, lifestyle variables, and dietary patterns of infants and mothers were tested using the chi-squared test.

Logistic regression model was performed to examine the associations between dietary patterns of infants and maternal socio-economic and lifestyle variables. This gives odds ratios (ORs) and their 95% confidence intervals (CIs), which indicate the multiplicative changes in the ratio of the probability of membership of cluster 2 (assumed as an event) to the probability of membership of cluster 1 (assumed as no event). All of the models were adjusted for all other potential predictive variables as follows: maternal age, pre-pregnancy body mass index, educational level, employment status, family income, family structure, mother has a husband, number of infant's older siblings, cigarette smoking assessed in pregnancy, physical activity level, duration of breastfeeding, age the infant was introduced to solid foods, infant's time allowance to watch TV or videos, and maternal dietary patterns.

All statistical analyses were performed using SAS statistical software version 9.1 (SAS Institute Inc.). A *P*-value of 0.05 was considered significant.

Results

Two clusters of dietary pattern were identified among infants (Table 1), which we descriptively labelled the 'fruits, vegetables and high-protein foods' and 'confectionaries and sweetened beverages' patterns based on their predominant food groups. The differences in food consumption profiles between dietary patterns were remarkable. The 'fruits, vegetables and high-protein foods' pattern ($n = 483$; 63.7%) was characterised by higher intakes of staple foods, meat, fish, eggs, vegetables, fruits, yogurt, and green and oolong teas, and the 'confectionaries and sweetened beverages' pattern ($n = 275$; 36.3%) by higher intakes of puddings and jellies, chocolate, rice crackers and several kinds of juices. No difference between the two dietary patterns was observed for age, anthropometric measurements at birth and 18 months, baby's gender, and season when the dietary data and proportion of commercial baby foods non-users were collected.

Table 2 shows maternal characteristics for socio-economic and lifestyle variables between the two dietary patterns of infants. Infants in the 'confectionaries and sweetened beverages' pattern were more likely to have mothers who were unemployed ($P = 0.007$) and daily smokers assessed in pregnancy ($P = 0.008$), and who had a lower educational level ($P < 0.001$), lower household income ($P < 0.001$), higher number of children ($P = 0.039$), shorter duration of breastfeeding ($P = 0.039$) and delayed introduction of solid foods to infants ($P = 0.029$) than those in the 'fruits, vegetables and high-protein foods' pattern. Some similarities in dietary patterns between mothers and infants were observed ($P < 0.001$). Infants in the 'fruits, vegetables and high-protein foods' pattern had a higher proportion of mothers in the 'rice, fish and vegetables' pattern and a lower proportion in the 'wheat products' pattern, with a relatively high intake of bread, confectionaries and soft drinks. In contrast, infants in the 'confectionaries and sweetened beverages' pattern had a higher proportion of mothers in the 'wheat products' pattern and a lower proportion in the 'rice, fish and vegetables' pattern.

Table 3 shows associations between the dietary patterns of infants and maternal socio-economic and lifestyle variables. Infants whose mothers were non-smokers and had a higher educational level, full-time employment, higher household income, longer duration of breastfeeding, and the 'rice, fish and vegetables' dietary pattern were less likely to belong to the 'confectionaries and sweetened beverages' than the 'fruits, vegetables and high-protein foods' pattern. After adjustment for all other predictive variables, maternal educational level, number of infant's older siblings and maternal dietary patterns were independently and significantly associated with the dietary patterns of infants. Infants whose mothers had an educational level more than 13 years (multivariate adjusted OR: 0.65, 95% CI: 0.44, 0.95) and the 'rice, fish and vegetables' dietary pattern (multivariate adjusted OR: 0.56, 95% CI: 0.36, 0.87) were less likely to belong to the 'confectionaries and sweetened beverages' pattern, whereas infants whose mothers had a

Table 2. Differences in maternal socio-economic and lifestyle characteristics between child's dietary patterns identified by cluster analysis: the Osaka Maternal and Child Health Study, Japan

Variable	All ($n = 758$)	Dietary pattern* Cluster 1: Fruits, vegetables and high-protein foods ($n = 483$)	Cluster 2: Confectionaries and sweetened beverages ($n = 275$)	P-value†
Maternal age (years, %)				
<30	46	44	50	0.085
≥30	54	56	50	
Pre-pregnancy BMI (kg m^{-2}, %)				
<18.5	23	23	24	0.298
18.5–24.9	73	74	71	
≥25.0	3	3	5	
Education (years, %)				
<13	28	22	38	<0.001
13–14	43	42	44	
≥15	29	35	19	
Employment status (%)				
Unemployment	71	67	78	0.007
Part-time employment	11	12	10	
Full-time employment	18	21	13	
Household income (Japanese yen $year^{-1}$, %)				
<4 000 000	28	24	35	<0.001
4 000 000–5 999 999	41	41	42	
≥6 000 000	31	36	24	
Family structure (%)				
Nuclear	88	89	87	0.384
Expanded	12	11	13	
Mother has a husband (%)				
No	2	2	3	0.148
Yes	98	98	97	
Number of infant's older siblings (%)				
0	50	54	44	0.039
1	40	37	45	
≥2	10	9	11	
Cigarette smoking assessed in pregnancy (%)				
Never	73	76	68	0.008
Former	11	12	11	
Current	16	13	22	
Physical activity level (%)				
Low	59	57	64	0.055
Moderate or high	41	44	36	
Duration of breastfeeding (months, %)				
<6	25	22	29	0.039
≥6	75	78	71	
Age of introduction of solid foods to infants (months, %)				
<5	15	14	16	0.029
5–6	74	77	68	
≥7	12	10	15	
Time infants permitted to watch television or videos (hours day^{-1}, %)				
<2	38	40	35	0.222
≥2	62	60	65	
Maternal dietary pattern (%)				
'Meat and eggs' pattern	53	52	54	<0.001
'Wheat products' pattern	26	22	32	
'Rice, fish and vegetables' pattern	22	26	14	

BMI, body mass index. *Cluster names were primarily based on food groups with high intakes. †P-value was calculated by chi-squared test.

Table 3. Crude and multivariate odds ratios (95% confidence intervals) of maternal socio-economic and lifestyle factors associated with 'Confectionaries and sweetened beverages' cluster of child's dietary pattern, estimated by multiple logistic regression analysis among 758 Japanese mother–child pairs: the Osaka Maternal and Child Health Study, Japan

Variable	Crude OR*	95% CIs	Multivariate OR†	95% CIs
Maternal age (years)				
<30	1.00		1.00	
≥30	0.77	(0.57, 1.04)	0.79	(0.56, 1.12)
Pre-pregnancy BMI (kg m^{-2})				
<18.5	1.00		1.00	
18.5–24.9	0.92	(0.65, 1.30)	1.07	(0.73, 1.56)
≥25.0	1.68	(0.74, 3.85)	2.03	(0.85, 4.84)
Education (years)				
<13	1.00		1.00	
13–14	0.61	(0.43, 0.87)	0.65	(0.44, 0.95)
≥15	0.31	(0.21, 0.47)	0.40	(0.25, 0.63)
Employment status				
Unemployment	1.00		1.00	
Part-time employment	0.67	(0.41, 1.10)	0.75	(0.44, 1.28)
Full-time employment	0.54	(0.35, 0.82)	0.84	(0.51, 1.38)
Household income (Japanese yen $year^{-1}$)				
<4 000 000	1.00		1.00	
4 000 000–5 999 999	0.71	(0.50 1.01)	0.83	(0.56, 1.22)
≥6 000 000	0.46	(0.31, 0.68)	0.66	(0.41, 1.06)
Family structure				
Nuclear	1.00		1.00	
Expanded	1.22	(0.78, 1.92)	1.05	(0.62, 1.77)
Mother has a husband				
No	1.00		1.00	
Yes	0.50	(0.19, 1.31)	0.57	(0.18, 1.76)
Number of infant's older siblings				
0	1.00		1.00	
1	1.48	(1.08, 2.03)	1.79	(1.24, 2.58)
≥2	1.43	(0.86, 2.38)	2.17	(1.21, 3.88)
Cigarette smoking assessed in pregnancy				
Never	1.00		1.00	
Former	1.05	(0.65, 1.69)	0.75	(0.45, 1.26)
Current	1.87	(1.26, 2.78)	1.22	(0.79, 1.90)
Physical activity level				
Low	1.00		1.00	
Moderate or high	0.74	(0.55, 1.01)	0.72	(0.51, 1.01)
Duration of breastfeeding (months)				
<6	1.00		1.00	
≥6	0.70	(0.50, 0.98)	0.91	(0.63, 1.32)
Age of introduction of solid foods to infants (months)				
<5	1.00		1.00	
5–6	0.75	(0.49, 1.13)	0.82	(0.52, 1.28)
≥7	1.31	(0.75, 2.30)	1.78	(0.97, 3.27)
Time infants permitted to watch television or videos (hours day^{-1})				
<2	1.00		1.00	
≥2	1.21	(0.89, 1.65)	1.04	(0.74, 1.46)
Maternal dietary pattern				
'Meat and eggs' pattern	1.00		1.00	
'Wheat products' pattern	1.41	(0.99, 1.99)	1.51	(1.04, 2.21)
'Rice, fish and vegetables' pattern	0.51	(0.34, 0.77)	0.56	(0.36, 0.87)

BMI, body mass index; OR, odds ratio; CIs, confidence intervals. *ORs indicate multiplicative changes in the ratio of probability of membership in the 'confectionaries and sweetened beverages' pattern (assumed as an event) to the probability of membership in the 'fruits, vegetables and high-protein foods' pattern (assumed as no event). †Adjusted for all other characteristics shown in the table.

higher number of infant's older siblings (multivariate adjusted OR: 1.79, 95% CI: 1.24, 2.58) and the 'wheat product' dietary pattern (multivariate adjusted OR: 1.51, 95% CI: 1.04, 2.21) were more likely to belong to the 'confectionaries and sweetened beverages' than the 'fruits, vegetables and high-protein foods' pattern.

Discussion

Using cluster analysis, we identified two distinct dietary patterns in a group of Japanese infants aged 16–24 months. In addition, we also found clear differences between these identified dietary patterns of infants in their mother's socio-economic status and dietary patterns. To our knowledge, this is the first study to investigate the association between the dietary patterns of infants and maternal socio-economic and lifestyle characteristics in a Japanese population.

In recent years, several study groups in Western countries have identified dietary patterns of infants and pre-school children using factor analysis or cluster analysis (North & Emmett 2000; Northstone & Emmett 2005; Robinson *et al*. 2007; Ovaskainen *et al*. 2009; Pryer & Rogers 2009; Ystrom *et al*. 2009; Manios *et al*. 2010; Moreira *et al*. 2010). Although the number of dietary patterns identified varied among studies, most studies identified two main dietary patterns, a healthy pattern rich in fruits and vegetable and an unhealthy pattern rich in fatty snacks and sugary foods. The former pattern was often labelled as 'healthy' (North & Emmett 2000; Ovaskainen *et al*. 2009; Pryer & Rogers 2009), 'health-conscious' (Northstone & Emmett 2005) or 'wholesome' patterns (Ystrom *et al*. 2009), and the latter as 'unhealthy' (Ystrom *et al*. 2009) or 'junk' patterns (North & Emmett 2000; Northstone & Emmett 2005). In the present study, we also identified two dietary patterns. The 'fruits, vegetables and high-protein foods' and 'confectionaries and sweetened beverages' patterns were comparable with the above healthy and unhealthy patterns, respectively. We observed similar dietary patterns of infants with the patterns observed in the other populations (Ovaskainen *et al*. 2009; Pryer & Rogers 2009; Ystrom *et al*. 2009), notwithstanding the differences in study populations, dietary assessment method used and dietary pattern approach.

The two dietary patterns identified in this study were remarkably different from one another. The infants in the 'confectionaries and sweetened beverages' pattern consumed less fruits (4.5 vs. 7.4 times $week^{-1}$) and vegetables (6.4 vs. 17.2 times $week^{-1}$), but much chocolate (1.4 vs. 0.7 times $week^{-1}$), rice crackers (2.3 vs. 1.7 times $week^{-1}$) and sweetened beverages (3.0 vs. 1.1 times $week^{-1}$) than those in the 'fruits, vegetables and high-protein foods' pattern. In particular, the difference in frequency of vegetable consumption was almost triple between two dietary patterns. The previous studies have shown that childhood diet may influence the development of chronic disease in later life (Ness *et al*. 2005; Mikkilä *et al*. 2007). The Boyd Orr cohort study has found that a higher childhood vegetable consumption had influenced on both diet in early old age (Maynard *et al*. 2006) and a lower risk of adult stroke (Ness *et al*. 2005). In the Finnish study, a clear tracking in dietary patterns was observed among subjects from childhood to adulthood over the 21-year period (Mikkilä *et al*. 2005), and a dietary pattern reflecting more health-conscious food choice (such as high consumption of vegetables, plant foods and dairy products) was inversely associated with cardiovascular risk factors (Mikkilä *et al*. 2007). Although the present study cannot provide information on the association between infantile dietary patterns and future health risk, at least nutrition education to promote healthy food choices (such as increasing fruits and vegetables) would be needed from the viewpoint of prevention especially for infants and their mothers who had a dietary pattern such as 'confectionaries and sweetened beverages' pattern.

Consistent with previous studies (Robinson *et al*. 2007; Ovaskainen *et al*. 2009), we found that maternal diet quality influenced children's dietary pattern. Infants whose mothers were in the 'wheat products' cluster, characterised by high intakes of bread, confectioneries, fruit and vegetable juice, and soft drinks, were more likely to be fed a comparable dietary pattern (cluster 2) (multivariate adjusted OR: 1.51, 95% CIs: 1.04, 2.21). In contrast, mothers in the 'rice, fish and vegetables' cluster, characterised by high intakes of rice, several kinds of vegetables, fish, fruits and miso soup, were more likely to provide their infants with a diet characterised by these foods (cluster 1) (multivariate adjusted OR: 1.79, 95% CI: 1.15, 2.78). In our study, the similarity between the dietary patterns of mothers and infants became apparent at 16–24 months of age, whereas Robinson *et al*. (2007) identified this similarity at 6 months. Given that the consistency between the dietary patterns of mother and child becomes more apparent with increasing child age (Robinson *et al*. 2007; Ovaskainen *et al*. 2009), factors influencing the child's diet should be regulated as soon as the child starts to eat solid foods.

Studies in adults have clearly established the association of socio-economic position and smoking status with diet quality (Fulton *et al*. 1988; Darmon & Drewnowski 2008). Studies focusing on women of reproductive age have consistently shown that lower educational attainment, lower income level and daily smoking were major predictors for their own diet quality (Robinson *et al*. 2004; Arkkola *et al*. 2008; Northstone *et al*. 2008). In addition to the mother's own diet quality, our present findings also show the important influence on dietary patterns of infants of maternal educational level (OR: 0.61, 95% CIs: 0.43, 0.87), employment status (OR: 0.54, 95% CIs: 0.35, 0.82), household income level (OR: 0.46, 95% CIs: 0.31, 0.68) and smoking status (OR: 1.87, 95% CIs: 1.26, 2.78). These findings are generally consistent with those of previous studies (North & Emmett 2000; Northstone & Emmett 2005; Robinson *et al*. 2007; Ovaskainen *et al*. 2009). After adjustment for all other predictive variables, however, we found that only maternal educational level retained a significant association. It is not clear exactly how maternal educational level influences children's diet. Mothers likely care about their children's diet more seriously during the infant feeding and weaning process, and, accordingly, have a greater need for knowledge of dietary recommendations for children's diet at this time. Their food choices for their children are thus likely determined based on their ability (i.e. education level) for understanding and applying dietary recommendations for practical use rather than on other socio-economic factors (e.g. employment status and income level).

Consistent with previous studies (North & Emmett 2000; Northstone & Emmett 2005; Robinson *et al*. 2007; Kourlaba *et al*. 2009), we also observed an effect of the presence of older siblings on the dietary pattern of infants: infants with older siblings were more likely to belong to the 'confectionaries and sweetened beverages' rather than 'fruits, vegetables and high-protein foods' cluster. This might be explained by the fact that mothers who have to care for more than one child find difficulty in making time to prepare meals because they are busy with the care of their children. Additionally, the older siblings may introduce foods such as snacks, confectionaries and soft drinks. This finding suggests that the dietary pattern of infants may be influenced not only by the mother but also by other family members. Potential family determinants of infant diet require further study.

Several limitations of the present study should be addressed. First, the subjects were not randomly sampled from the general population, but were selected, and the survey area was restricted to a single prefecture in Japan. The participants were therefore likely not representative of Japanese mother–child pairs. Second, the dietary data of infants were obtained from a non-validated questionnaire, which was developed for this survey. The food types used in the questionnaire were selected to assess general patterns of food intake rather than specific nutritional components, and we were accordingly unable to assess the differences between clusters in diet quality at the nutrient level. Third, information on socio-economic and lifestyle variables relied on the participant's self-reported. Higher socio-economic groups generally have greater knowledge of dietary recommendations (Winkleby *et al*. 1992) and may therefore be more incline to report 'more favourable' dietary behaviours (Macdirmid & Blundell 1998). We cannot quantify the effects of possible reporting error on the results of this study because of a lack of information on reporting bias associated with socio-economic position. Fourth, infantile dietary data and maternal information such as socio-economic position, health-related behaviours and dietary intake were evaluated in different time periods, the former at 16- to 24-month post-partum and the latter during pregnancy. In addition, we could not obtain information on occupation or household income level after the birth of infants. This time gap in assessment between mothers and infants might have therefore slightly influenced the results. However, maternal education and the number of older siblings in relation to infantile dietary patterns were likely robust because these variables would not have changed between survey times. Fifth, maternal body weight just before pregnancy was not available. Instead, we used self-reported body weight at age 20 years. However, the possibility of recall bias regarding body size cannot be ruled out. Therefore, the results should be interpreted with caution. Finally, we did not assess the effects of paternal or other family member influence on the diets of infants. Furthermore, as other potential relevant factors, the type of day care (i.e. at home or in kindergarten), a main caregiver of children during weekdays, source of information on feeding practice for children, and maternal motivation for adhering to dietary recommendations were not obtained in the present study because of a lack of information. Therefore, further studies with consideration of these possible factors are required.

The cluster analysis itself also has several limitations that stem from several subjective or arbitrary decisions that investigators must make. In the *K*-means method, one major subjective decision during analytical process is to pre-define the number of cluster solutions to retain, which can force the data into unrealistic clusters. To identify the optimal number of clusters, we conducted exploratory analysis to obtain information on cluster seeds. In addition, we conducted several runs with varying number of clusters. To test the robustness of cluster solutions, two methods were used: (1) discriminant analysis to test the degree of association between group membership assigned by cluster analysis using 15 food items (95.8% of subjects were classified correctly) and (2) by randomly dividing the data into halves, clustering separately in each subset and comparing cluster membership in each divided sample. However, it should be noted that reproducibility of cluster solutions does not necessarily guarantee validity. To the best of our knowledge, few studies addressing methodological issues of cluster analysis have been reported (Lo Siou *et al*. 2011). Therefore, further methodological work of clustering is required in nutritional epidemiology, which will help to establish more appropriate dietary pattern approach.

In conclusion, we found that the mother's socio-economic position and dietary pattern were associated with the dietary patterns of Japanese infants aged 16–24 months. Because the acquisition of healthful dietary habits in early childhood is an important public health topic for the prevention of chronic diseases in adulthood, further research is required to determine whether the results obtained in this group would also be observed in a more representative sample of the Japanese population.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

HO conducted the statistical analyses and wrote the manuscript. YM and SS contributed to the planning of the OMCHS and data collection and assisted in manuscript preparation. KT contributed to data collection. KM assisted in manuscript preparation. YH supervised the design and execution of the OMCHS.

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