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Maternal dietary patterns in pregnancy and fetal growth in Japan: the Osaka Maternal and Child Health Study

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Abstract

Maternal nutritional status during pregnancy is an important determinant of fetal growth. Although the effects of several nutrients and foods have been well examined, little is known about the relationship of overall maternal diet in pregnancy to fetal growth, particularly in non-Western populations. We prospectively examined the relationship of maternal dietary patterns in pregnancy to neonatal anthropometric measurements at birth and risk of small-for-gestational-age (SGA) birth among 803 Japanese women with live-born, singleton, term deliveries. Maternal diet in pregnancy was assessed using a validated, self-administered diet history questionnaire. Dietary patterns from thirty-three predefined food groups (g/4184 kJ) were extracted by cluster analysis. The following three dietary patterns were identified: the 'meat and eggs' (*n* 326), 'wheat products', with a relatively high intake of bread, confectioneries and soft drinks (*n* 303), and 'rice, fish and vegetables' (*n* 174) patterns. After adjustment for potential confounders, women in the 'wheat products' pattern had infants with the significantly lowest birth weight ($P=0·045$) and head circumference ($P=0·036$) among those in the three dietary patterns. Compared with women in the 'rice, fish and vegetables' pattern, women in the 'wheat products' pattern had higher odds of having a SGA infant for weight (multivariate OR 5·2, 95 % CI 1·1, 24·4), but this was not the case for birth length or head circumference. These results suggest that a diet high in bread, confectioneries, and soft drinks and low in fish and vegetables during pregnancy might be associated with a small birth weight and an increased risk of having a SGA infant.

Key words: Cohort studies: Maternal dietary patterns: Fetal growth: Cluster analysis: Japanese pregnant women

Evidence suggests that restricted fetal growth is associated with not only an increased risk of neonatal mortality and morbidity, but also an increased risk of developing chronic disease in adulthood, such as CVD, type 2 diabetes and hypertension[1,2]. Identification of modifiable risk factors that influence fetal growth is therefore important from the perspective of preventive medicine.

As one modifiable risk factor[3], adequate maternal nutritional status during pregnancy has long been accepted as vital to fetal growth via the creation of an optimal intra-uterine environment. Until recently, many epidemiological studies have examined the relationship between fetal growth outcomes and the maternal intake of food groups and nutrients, including fruits and vegetables[4,5], fish[6,7], dairy products[8,9], protein[10–12], carbohydrate[10–12], fatty acids[13,14], vitamins[9,15–18] and glycaemic index[19]. However, no clear relationship has yet been established.

In contrast to these studies, which focused attention on single nutrients or foods, we are aware of only four studies which have investigated the relationship between maternal diet and fetal growth using the dietary pattern approach, which measures overall diet by combinations of foods rather than the traditional single-nutrient approach[20–23]. In a Mexican-American survey using factor analysis, nutrient-dense (fruits, vegetables and low-fat dairy) and protein-rich (low-fat meats, processed meats and dairy desserts) eating patterns were associated with increased birth weight, while a transitional (fats and oils, bread and cereals, high-fat meats and sugar) eating pattern was associated with decreased birth weight[20]. Similar studies have also been conducted in

Abbreviations: DHQ, diet history questionnaire; OMCHS, Osaka Maternal and Child Health Study; SGA, small-for-gestational-age.

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Denmark[21], the UK[22] and New Zealand[23]. All these four studies were conducted in Western countries. No such studies exist in Asian countries, including Japan. Furthermore, all studies on the identification of dietary patterns for this topic have been conducted primarily using factor analysis[20–23], but no such study has been performed using cluster analysis.

Factor analysis and cluster analysis are two commonly used statistical methods for empirically deriving dietary patterns. Factor analysis reduces dietary data into patterns based on intercorrelations between food intakes, and individuals receive factor scores for each derived dietary pattern[24,25]. Although this approach has good statistical power to detect associations with outcome variables because of ranking individuals according to the degree to which they adhere to the dietary pattern, factor scores are somewhat abstract, and do not provide a clear description of exactly what is being consumed, as the same score may be obtained with different combinations of foods[25]. On the other hand, cluster analysis creates mutually exclusive groups of people with relatively homogeneous food intake, and individuals belong to only one identified cluster[24,25]. This approach provides a clear description of what subgroups are consuming[25]. Cluster analysis, rather than factor analysis, is therefore a useful way to focus attention on groups of people with a good or poor nutritional status and to design nutrition intervention for pregnant women with a higher risk of having a small-for-gestational-age (SGA) infant.

We have previously identified dietary patterns, namely the 'meat and eggs', 'wheat products' and 'rice, fish and vegetables' patterns, by cluster analysis in Japanese pregnant women, and examined the nutritional adequacy based on the Dietary Reference Intakes for Japanese[26]. However, in that report, no health outcomes were used for examining the relationship with the adequacy of the identified dietary patterns. Here in the present study, we prospectively examined the relationship of maternal dietary patterns in pregnancy to neonatal anthropometric measurements at birth among 803 Japanese women using the same data from the Osaka Maternal and Child Health Study (OMCHS)[26–28]. Our hypothesis is that women with the lowest nutritional adequacy of dietary pattern in pregnancy ('wheat products' pattern) would be associated with a small birth weight and an increased risk of having a SGA infant compared with women with the highest one ('rice, fish and vegetables' pattern).

Subjects and methods

Study population and procedure

The present study was based on data from the OMCHS, a prospective cohort study that investigated preventive and risk factors for maternal and child health problems. The principal objective of the OMCHS is to clarify risk factors for childhood allergic disorders. Details of the OMCHS have been published elsewhere[27,28]. Briefly, all pregnant women in Neyagawa City, Osaka Prefecture, Japan, were recruited between November 2001 and March 2003. Of the 3639 eligible women, 627 (17·2 %) took part in the study. An additional 375 pregnant women living in other neighbourhood areas were enrolled between December 2001 and November 2003. Baseline assessment of the OMCHS was primarily conducted using a set of two self-administered questionnaire on dietary habits and a wide range of lifestyle behaviours. A third self-administered questionnaire was additionally answered after the birth of infants in the second survey. The participants mailed these answered questionnaires to the data management centre at the time the survey was conducted. Research technicians completed missing or illogical data by telephone interview. A total of 1002 pregnant women at 5–39 weeks of gestation completed the baseline survey, of whom 867 completed the second survey at 2–9 months postpartum.

For the present study, we restricted our analysis to 813 women with live-born, singleton, term deliveries (37–41 weeks of gestation) to eliminate potential confounding by twinning and pre- and post-term delivery, resulting in the exclusion of seven and fifty-one subjects, respectively. Of the remaining 813 subjects, we excluded ten subjects with no information on infant birth length (*n* 1), head circumference (*n* 1), maternal body weight at 20 years used as pre-pregnancy body weight (*n* 7), or maternal gestational weight gain (*n* 2). As some subjects were in more than one exclusion category, the final analyses comprised 803 women.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the ethics committee of the Osaka City University School of Medicine. Written informed consent was obtained from all subjects.

Dietary assessment

In the baseline survey, we collected information on dietary habits during the preceding month using a validated, self-administered, comprehensive diet history questionnaire (DHQ)[29,30]. The DHQ is a structured sixteen-page questionnaire that asks about the consumption frequency and portion size of selected foods commonly consumed in Japan, general dietary behaviours and usual cooking methods[30]. Estimates of daily intake for 150 food and beverage items, energy and nutrients were calculated using an *ad hoc* computer algorithm for the DHQ, which was based on the Standard Tables of Food Composition in Japan[31]. Information on dietary supplements was not used in the calculation of dietary intake because of the lack of reliable composition data in Japan. The methods used to calculate dietary intake and the validity of the DHQ have been detailed elsewhere[29,30]. Food intake values were energy-adjusted using the energy-density model, i.e. g/4184 kJ, both to reduce the measurement error common with dietary assessment questionnaires[32,33] and to avoid biased grouping due to variation in body size and energy requirement[32].

Identification of dietary patterns

Before identification of dietary patterns, food items were grouped together to reduce complexity. The 150 food items included in the DHQ, excluding three items (nutritional supplement bars, soup of the noodle and drinking-water) because of a difficulty in classification, were grouped into thirty-three food groups[26] by combining items of similarity of nutrient profiles and culinary usage of the foods.

Dietary patterns were generated by *K*-means cluster analysis using the FASTCLUS procedure in SAS (SAS Institute, Inc., Cary, NC, USA). Before cluster analysis, intakes of energy-adjusted food group (g/4184 kJ) were standardised to a mean of zero and a standard deviation of 1 to remove the extraneous effect of variables with large variances. We identified three clusters of dietary pattern, namely the 'meat and eggs', 'wheat products' and 'rice, fish and vegetables' patterns. The details of food and nutrient intakes across these clusters have been published elsewhere[26]. Briefly, the 'meat and eggs' pattern was characterised by a high intake of beef and pork, processed meat, chicken, eggs, butter and dairy products. The 'wheat products' pattern was characterised by a high intake of bread, confectioneries, fruit and vegetable juice, and soft drinks. The 'rice, fish and vegetables' pattern was characterised by a high intake of rice, potatoes, nuts, pulses, fruits, green and yellow vegetables, white vegetables, mushrooms, seaweeds, Japanese and Chinese tea, fish, shellfish, sea products, miso soup and salt-containing seasoning.

We have evaluated the reliability of the dietary patterns by examining their stability and classification ability using discriminant analysis. This analysis was performed on the three clusters using the thirty-three food groups as discriminant variables and the 803 subjects originally clustered as the sample. From the discriminant analysis, classification functions were developed and used to assign each subject into one of the three clusters. Subjects were then cross-classified according to their original cluster classification and the one obtained from the discriminant analysis. Discriminant analysis correctly classified 94·2 % of the study subjects. When each of the original clusters was considered separately, the sensitivity of the discriminant analysis was as follows: 94·8 % for the 'meat and eggs', 94·1 % for the 'wheat products' and 93·7 % for the 'rice, fish and vegetables' patterns.

Anthropometric measurements at birth

Information on neonatal anthropometric measurements at birth and gestational age at birth was obtained from a self-administered questionnaire in the second survey[28]. In Japan, birth weight (g), birth length (cm) and head circumference (cm) are generally measured just after birth in the hospital and recorded in the birth records. Gestational age is generally estimated on the basis of the first day of the last menstrual period, and confirmed by ultrasound at the first routine health check-up in each hospital. Information on the baby's sex, neonatal anthropometric measurements and gestational age at birth is also recorded by the obstetrician or midwife in the Maternal and Child Health Handbook (*Boshi-techo*), which is issued by the local municipal government to all prospective mothers at the confirmation of pregnancy and used to record all events during pregnancy, delivery and postpartum. The women participating in the present study were asked to refer to the information recorded in their own Maternal and Child Health Handbook. Outcome variables used in the study were birth weight, birth length and head circumference standardised for gestational age using the residual method. SGA infants were defined as infants with birth anthropometric measurements below the 10th percentile of the Japanese gestational age- and sex-specific reference growth curves[34].

Assessment of lifestyle variables and confounders

Potential confounding factors were selected from previously reported determinants of fetal growth[3,35]. The three kinds of self-administered questionnaires used in the present study also elucidated information on sociodemographic variables, lifestyle and other potential confounding factors. At the baseline survey, we obtained information on maternal age (<29, 29–31 and ≥32 years), maternal height (cm), week of gestation at baseline survey (weeks), parity (primiparous or multiparous), cigarette smoking (never, former and current), dietary change in the previous 1 month (none or seldom, slight and substantial), dietary supplement use (yes and no), physical activity level at baseline (low and moderate or high), family structure (nuclear and expanded), occupation (housewife and outside work), education (<13, 13–14 and ≥15 years), household income (<4 000 000, 4 000 000–5 999 999 and ≥6 000 000 Japanese yen/year), and season in which data in the baseline survey were collected (spring, summer, autumn and winter). In the second survey, information on medical problems in pregnancy (yes and no), baby's sex (boy and girl) and maternal gestational weight gain (kg) were obtained. Maternal body weight at age 20 years was used as pre-pregnancy body weight because of a lack of information on maternal body weight just before pregnancy. Pre-pregnancy BMI (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).

Statistical analysis

To describe the characteristics of the three clusters (dietary patterns), we calculated subject characteristic means (95 % CI) and frequencies for each cluster separately. Differences in mean subject characteristics across the dietary patterns were tested using ANOVA with Tukey–Kramer's adjustment for multiple comparisons. The χ^2 test was used to examine the differences in variables expressed as a proportion, such as sociodemographic characteristics and lifestyle variables. Mean and multivariate-adjusted mean differences in neonatal anthropometric measurements across the dietary patterns were assessed using general linear models (PROC GLM procedure). The crude and multivariate-adjusted OR and 95 % CI of having a SGA infant were calculated by logistic regression analysis. The 'rice, fish and vegetables' pattern was considered as the reference group because this dietary pattern showed a better nutritional profile with the lowest prevalence of inadequacy for many essential micronutrients in our previous study[26]. All of the models were adjusted for maternal age, parity, maternal height, pre-pregnancy BMI, gestational weight gain, week of gestation at baseline survey, cigarette smoking, change in diet in the previous 1 month, dietary supplement use, physical activity level, family structure, occupation, family income, education, season in which data at baseline were collected, medical problems in pregnancy and baby's sex.

All statistical analyses were performed using SAS statistical software version 9.1 (SAS Institute, Inc.). All reported P values are two-tailed, and $P<0.05$ was considered to be statistically significant.

Results

Table 1 shows subject characteristics across the three dietary patterns. The women in the 'rice, fish and vegetables' pattern

Table 1. Subject characteristics across the three dietary patterns identified by cluster analysis among 803 Japanese pregnant women who participated in the Osaka Maternal and Child Health Study, Japan

(Percentages, mean values and 95 % confidence intervals)

	Dietary pattern (%)*			
Variables	Meat and eggs (*n* 326)	Wheat products (*n* 303)	Rice, fish and vegetables (*n* 174)	*P*†
Maternal age (%)				
<29 years	39·0	40·9	27·0	<0·001
29–31 years	25·5	28·4	43·1	
≥ 32 years	35·6	30·7	29·9	
Parity of 1 or more (%)	54·3	48·2	52·9	0·290
Cigarette smoking (%)				
Never	74·9	65·4	76·4	0·012
Former	10·4	13·5	13·2	
Current	14·7	21·1	10·3	
Dietary change in the previous 1 month compared with pre-pregnancy (%)				
None or seldom	31·0	27·1	24·1	0·123
Slight	46·9	42·6	48·3	
Substantial	22·1	30·4	27·6	
Diet supplement user (%)	19·2	19·3	28·9	0·023
Physical activity level (%)				
Low	58·0	62·4	54·6	0·228
Moderate or high	42·0	37·6	45·4	
Nuclear family structure (%)	88·3	89·8	85·1	0·306
Occupation (%)				
Housewife	73·3	67·0	73·0	0·172
Outside work	26·7	33·0	27·0	
Education (%)				
< 13 years	30·4	31·0	21·8	0·005
13–14 years	40·8	46·5	40·2	
≥ 15 years	28·8	22·4	37·9	
Household income (%)				
< 4 000 000 (Japanese yen/year)	30·1	29·0	25·3	0·452
4 000 000–5 999 999 (Japanese yen/year)	37·4	42·9	40·8	
≥ 6 000 000 (Japanese yen/year)	32·5	28·1	33·9	
Season when data were collected (%)				
Spring	29·5	36·6	29·3	0·317
Summer	19·0	13·9	15·5	
Autumn	23·3	20·8	22·4	
Winter	28·2	28·7	32·8	
Medical problems in pregnancy (%)‡	12·6	14·5	10·3	0·416
Baby's sex (boy, %)	57·4	49·2	51·7	0·112
Week of gestation at baseline (weeks)				
Mean	18·0	18·0	18·1	
95 % CI	17·2, 18·8	17·1, 18·8	17·2, 19·0	0·986
Maternal height (cm)				
Mean	158·2	158·1	158·6	0·566
95 % CI	157·7, 158·8	157·5, 158·6	157·8, 159·4	
Pre-pregnancy BMI (kg/m^2)				
Mean	20·2	20·2	20·1	0·885
95 % CI	20·0, 20·4	19·9, 20·5	19·7, 20·4	
Gestational weight gain (kg)				
Mean	10·0^{a,b}	10·2^{a}	9·3^{b}	0·010
95 % CI	9·7, 10·3	9·8, 10·6	8·8, 9·7	

^{a,b} Mean values within a row with unlike superscript letters were significantly different ($P<0.05$, Tukey–Kramer's adjustment for multiple comparisons).
* Cluster names were basically based on food groups with high intakes.
† P value was calculated by ANOVA for continuous variables and the χ^2 test for categorical variables to test differences between the clusters.
‡ Hyperemesis, hydramnios, oligoamnios, gestosis, abruptio placenta, placenta previa, incompetent cervical os or others diagnosed by a medical doctor.

were more likely to be non-smokers, supplement users, have a higher education level and have less gestational weight gain. In contrast, the women in the 'wheat products' pattern were more likely to be younger, current smokers, have a lower education level and a higher gestational weight gain. Characteristics of the women in the 'meat and eggs' pattern were intermediate between those of subjects in the other two patterns.

Table 2 shows the mean and multivariate-adjusted mean neonatal anthropometric measurements across the three dietary patterns. After adjustment for potential confounding factors, significant differences in birth weight ($P=0·045$) and head circumference ($P=0·036$) were observed across the dietary patterns. The women in the 'wheat products' pattern had infants with significantly lower birth weight ($P=0·013$) and head circumference ($P=0·011$) than those in the 'rice, fish and vegetables' pattern.

Table 3 shows crude and multivariate-adjusted OR (95 % CI) of having a SGA infant for birth weight, birth length and head circumference across the three dietary patterns. Compared with women in the 'rice, fish and vegetables' pattern, those in the 'wheat products' pattern had significantly higher odds of having a SGA infant for body weight after adjustment for potential confounding factors (multivariate OR 5·24, 95 % CI 1·13, 24·4). However, this was not the case for birth length and head circumference. No significant difference in the risk of having a SGA infant was observed between women in the 'meat and eggs' and 'rice, fish and vegetables' patterns.

Discussion

In the present cohort study of a group of Japanese pregnant women, we observed the relationship of maternal dietary patterns in pregnancy to neonatal anthropometric measurements at birth and the risk of having a SGA infant. After adjustment for potential confounding factors, women in the 'wheat products' pattern, characterised by a high intake of bread, confectioneries, fruit and vegetable juice, and soft drinks, had infants with lower birth weight and head circumference and a higher risk of having a SGA infant for weight than those in the 'rice, fish, and vegetable' pattern. Thus, our hypothesis that women in the lowest nutritional adequacy of dietary pattern would be associated with an increased risk of having a SGA infant was supported by the present findings.

The number of epidemiological studies of the relationship between dietary patterns in pregnancy and fetal growth is limited[20–23]. Furthermore, all studies on the identification of dietary pattern for this topic have been conducted primarily using factor analysis[20–23]. To our knowledge, the present study is the first one to examine the relationship between maternal dietary patterns in pregnancy defined by cluster analysis and neonatal anthropometric measurements at birth in a non-Western population. A prospective study using factor analysis among Mexican-Americans has shown that nutrient-dense (fruits, vegetables and low-fat dairy) and protein-rich (low-fat meats, processed meats and dairy dessert) eating patterns were associated with increased birth weight, while a transitional (fats and oils, bread and cereals, high-fat meats and sugar) eating pattern was associated with decreased birth weight[20]. A second prospective study conducted in Denmark[21] has found that women in the 'Health conscious' class, characterised by a high intake of fruits, vegetables, fish and poultry, and the lowest intake of meat and fat of animal origin, had a significantly lower risk of having a SGA infant than those in the 'Western diet' class, characterised by a high intake of red and processed meats, potatoes, and high-fat dairy, and a low intake of fruits and vegetables (multivariate

Table 2. Neonatal anthropometric measurements at birth across the three dietary patterns identified by cluster analysis among 803 Japanese pregnant women who participated in the Osaka Maternal and Child Health Study, Japan

(Mean values and 95 % confidence intervals)

	Dietary pattern						
	Meat and eggs (*n* 326)		Wheat products (*n* 303)		Rice, fish and vegetables (*n* 174)		
Variables	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	*P**
Birth weight (g)†							
Crude	3114	3078, 3151	3072	3033, 3112	3137	3084, 3191	0·107
Adjusted‡	$3105^{a,b}$	3069, 3141	3073^{a}	3036, 3111	3153^{b}	3104, 3203	0·045
Birth length (cm)†							
Crude	49·0	48·8, 49·1	48·9	48·7, 49·0	49·2	48·9, 49·4	0·182
Adjusted‡	48·9	48·7, 49·1	48·9	48·7, 49·1	49·2	48·9, 49·4	0·177
Head circumference (cm)†							
Crude	33·4	33·3, 33·6	33·2	33·0, 33·4	33·5	33·2, 33·8	0·060
Adjusted‡	$33·4^{a,b}$	33·2, 33·5	$33·2^{a}$	33·0, 33·4	$33·6^{b}$	33·3, 33·8	0·036

a,b Mean values within a row with unlike superscript letters were significantly different ($P<0·05$, Tukey–Kramer's adjustment for multiple comparisons in general linear models).

* *P* value was calculated by ANOVA in general linear models.

† Neonatal anthropometric measurements at birth were adjusted for gestational age.

‡ Adjusted for maternal age (<29, 29–31 and ≥32 years), parity (0 and ≥1), maternal height (cm), maternal pre-pregnancy BMI (kg/m^2), gestational weight gain (kg), week of gestation at baseline survey (weeks), cigarette smoking (never, former and current), change in diet in the previous 1 month (none or seldom, slight and substantial), dietary supplement use (yes and no), physical activity level (low and moderate or high), family structure (nuclear and expanded), occupation (housewife and outside work), family income (<4 000 000, 4 000 000–5 999 999 and ≥6 000 000 yen/year), education (<13, 13–14 and ≥15 years), season in which data at baseline were collected (spring, summer, autumn and winter), medical problems in pregnancy (yes and no) and baby's sex (boy and girl).

Table 3. Crude and multivariate OR of having a small-for-gestational-age (SGA) infant for neonatal anthropometric measurements at birth across the three dietary patterns identified by cluster analysis among 803 Japanese pregnant women who participated in the Osaka Maternal and Child Health Study, Japan

(Odds ratios and 95 % confidence intervals)

	Dietary pattern					
	Meat and eggs (*n* 326)		Wheat products (*n* 303)		Rice, fish and vegetables (*n* 174)	
Variables	OR	95 % CI	OR	95 % CI	OR	
Birth weight (g)						
n with SGA*	15		17		2	
Crude	4·15	0·94, 18·4	5·11	1·17, 22·4	1·00	Reference
Multivariate†	4·32	0·92, 20·3	5·24	1·13, 24·4	1·00	Reference
Birth length (cm)						
n with SGA*	25		22		13	
Crude	1·03	0·51, 2·07	0·97	0·48, 1·98	1·00	Reference
Multivariate†	1·04	0·50, 2·16	0·98	0·46, 2·09	1·00	Reference
Head circumference (cm)						
n with SGA*	28		27		15	
Crude	1·00	0·52, 1·92	1·04	0·54, 2·01	1·00	Reference
Multivariate†	1·12	0·56, 2·24	1·07	0·53, 2·16	1·00	Reference

* Newborns with a birth weight, length and head circumference below the 10th percentile according to the Japanese infant reference growth charts for sex and gestational age, 2000[32], were classified as being SGA for weight, length or head circumference.

† Adjusted for maternal age (<29, 29–31 and ≥32 years), parity (0 or ≥1), maternal height (cm), maternal pre-pregnancy BMI (kg/m^2), gestational weight gain (kg), week of gestation at baseline survey (weeks), cigarette smoking (never, former and current), change in diet in the previous 1 month (none or seldom, slight and substantial), dietary supplement use (yes and no), physical activity level (low and moderate or high), family structure (nuclear and expanded), occupation (housewife and outside work), family income (<4 000 000, 4 000 000–5 999 999 and ≥6 000 000 yen/year), education (<13, 13–14 and ≥15 years), season in which data at baseline were collected (spring, summer, autumn and winter), medical problems in pregnancy (yes and no) and baby's sex (boy and girl).

OR 0·74, 95 % CI 0·64, 0·86). A UK study has found a positive association between a 'Health conscious' pattern and birth weight[22], while a very recent case–control study in New Zealand[23] has shown that the 'traditional' diet in early pregnancy, characterised by a high intake of meat, potatoes, carrots, peas, fruits and several kinds of vegetables, was associated with a decreased risk of having a SGA infant. In the present study, the women in the 'rice, fish and vegetables' pattern had infants with significantly higher average birth weight (P=0·013) and a lower risk of having a SGA infant compared with those in the 'wheat products' pattern (OR 0·19, 95 % CI 0·04, 0·89). The present finding is generally in agreement with these previous studies[20–23]. These previous studies and the present study together suggest that, notwithstanding the differences in study population, design, dietary assessment method used, dietary pattern approach and potential confounding factors considered, a dietary pattern with a greater intake of vegetables, fruits and lean meat may have a greater capacity to reduce the risk of having a SGA infant.

Previous studies, which examined the risk to fetal growth of overall diet quality, rather than of a single nutrient, might be more interesting and worthy of discussion. Of two prospective studies of overall diet quality using the Alternate Healthy Eating Index, an inverse association between the Alternate Healthy Eating Index score and the risk of having a SGA infant was observed in a Spanish study[36], but not in a US study[37]. A Canadian study has reported that maternal diet quality, as assessed using a total mean adequacy ratio for twelve nutrients, was significantly related to infant birth weight and crown–heel length[38]. Using the same dataset of Japanese pregnant women[26], we previously examined the relationship between maternal dietary patterns and overall nutritional adequacy with the indices of the Dietary Reference Intakes for Japanese as a temporal gold standard. The women in the 'wheat products' pattern had the highest prevalence of nutritional inadequacy than those in the 'meat and eggs' and the 'rice, fish and vegetables' patterns[26]. In this regard, the present finding may support previous observations that maternal diet quality is related to fetal growth[36,38].

Several limitations of the present study warrant mention. First, the study subjects were not a representative sample of Japanese women in the general population, and the present findings might not be generalised, although the relatively high follow-up rate (80·1 %) minimised the possibility of bias by loss of follow-up. Second, because our sample size was relatively small compared with the previous studies[21–23], statistical power may have been insufficient to allow the detection and stability of results of the association between maternal dietary patterns and the risk of having a SGA infant. Because of the small proportion of SGA infants in the reference group of women in the 'rice, fish and vegetables' pattern, the risk of having a SGA infant for weight showed a higher OR and wide 95 % CI among women in the 'wheat products' pattern (multivariate OR 5·24, 95 % CI 1·13, 24·4), and the results should accordingly be interpreted with caution. Third, although we used a validated dietary assessment questionnaire, its ability to estimate total food and nutrient intake remains a serious concern, and incompleteness of the assessment cannot be ruled out. Furthermore, misreporting of self-reported food intake is a source of measurement error, particularly with regard to under- rather than over-reporting[32,33]. To minimise the influence of under-reporting, we used energy-adjusted values[32]. Fourth, the study included participants with various gestational ages (5–39 weeks). According to a previous report, maternal diet in early pregnancy may be more important to the development and differentiation of various organs, whereas diet in late pregnancy may be important for overall fetal growth as well as for brain development[39]. However, several previous longitudinal studies have reported that dietary habits remained relatively consistent throughout pregnancy[40,41]. Fifth, maternal body weight just before pregnancy was not available. Instead, we used body weight at age 20 years. Finally, although we attempted to adjust for a number of potential confounding variables, unknown or poorly measured confounders could not be controlled. In particular, we could not control for paternal body height because of a lack of information. In addition, the validity and reliability of potential confounding factors from self-administered questionnaires developed for the present study are questionable because of a lack of validation study. Therefore, the results should be interpreted with caution.

In conclusion, the present preliminary prospective study in Japanese pregnant women showed that a dietary pattern with a high intake of bread, confectioneries and soft drinks, and a low intake of fish and vegetables during pregnancy might be associated with a small birth weight and an increased risk of having a SGA infant. Because of a small sample size, however, we cannot rule out the possibility that the association observed in the present study was due to chance. Accordingly, further large-scale prospective studies are required to confirm the relationship between maternal dietary patterns and fetal growth.

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Appendix

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