JNS
JOURNAL OF NUTRITIONAL SCIENCE

RESEARCH ARTICLE

Association between diet quality during pregnancy of mothers and that of 3-year-old offspring: a prospective hospital-based birth cohort study

Yuki Tada[1,2]*, Kazue Ishitsuka[2], Aurélie Piedvache[2], Hisako Tanaka[2], Kohei Ogawa[2,3], Minatsu Kobayashi[2,4], Reiko Horikawa[5], Takeo Fujiwara[2,6] and Naho Morisaki[2]

[1]*Department of Nutritional Science, Faculty of Applied Bioscience, Tokyo University of Agriculture, Tokyo, Japan*
[2]*Department of Social Medicine, National Center for Child Health and Development, Tokyo, Japan*
[3]*Center of Maternal-fetal, Neonatal and Reproductive Medicine, National Center for Child Health and Development, Tokyo, Japan*
[4]*Department of Food Science, Otsuma Women's University, Tokyo, Japan*
[5]*Division of Endocrinology and Metabolism, National Center for Child Health and Development, Tokyo, Japan*
[6]*Department of Public Health, Tokyo Medical and Dental University, Tokyo, Japan*

(Received 16 October 2023 – Revised 1 March 2024 – Accepted 21 March 2024)

Journal of Nutritional Science (2024), vol. 13, e26, page 1 of 11 doi:10.1017/jns.2024.24

Abstract

Children's eating habits are established early in life and parents play a major role therein. Pregnancy is a teachable moment for the promotion of healthy eating because many women are concerned about their babies' health and have frequent contact with healthcare providers. We aimed to investigate the association between diet quality during pregnancy and the offspring. A total of 691 sets of data on pregnant mothers and their 3-year-old offspring were obtained from the Seiiku Boshi cohort study. Dietary intake was assessed using a validated food frequency questionnaire for mothers in mid-to-late pregnancy and a validated diet history questionnaire for Japanese preschool children at the 36-month checkup. Diet quality was scored using the Japanese Food Guide Spinning Top. Maternal diet quality score was categorised into quartiles, and the association between offspring and maternal diet quality score, adjusted for socioeconomic factors, was assessed using multiple linear regression. The total offspring diet quality score showed a linear trend with the maternal diet quality score (the mean increments (confidential intervals) for each quartile were –0.12 (–1.32–1.08), 1.54 (0.34–2.73), and 1.22 (0.03–2.42)). In particular, offspring vegetable dishes scored higher in all quartiles of maternal vegetable dish scores than in the lowest quartile (0.69 (0.21–1.17), 0.97 (0.50–1.45), and 1.36 (0.88–1.83)). A high diet quality score during pregnancy was positively associated with that of offspring, suggesting the importance of nutritional education in pregnant women to improve their diet quality.

Key words: **Birth cohort: Diet quality: Japan: Preschool children: Pregnant women**

Introduction

Dietary habits and quality are important for healthy eating and growth to promote good health and prevent illness in adulthood.[1] Food behaviour and specific food choices are established early in life and become stable in the long term.[2] Interventions in school-age children are not always successful, with a systematic review of interventions to increase fruit and/or vegetable consumption in obese or overweight children showing inconsistent results, suggesting that they are unlikely to achieve long-term changes in dietary behaviour.[3]

The critical time for dietary change occurs between the ages of 1.5 years and 3 years, wherein the diet tends to move decisively toward an increased intake of added sugars, and lower fruit and vegetable intake tendencies are established.[4] Toddlers as small as 1–2 years old may not consume enough vegetables, cereals, and grains and instead consume discretionary foods.[5]

* **Corresponding author:** Yuki Tada, email: y3tada@nodai.ac.jp

Health behaviours are influenced by social environment and personal factors, as suggested by the model of triadic reciprocal causation[6]; social environmental factors play a major role in food choices. The mother's health behaviours and parenting strategies mediate the relationship between the effects of family-based interventions on the child's dietary behaviours and diet.[7] Furthermore, parental intake is positively associated with children's fruit and/or vegetable consumption,[8] especially among those who are conscious of eating all their vegetables.[9] Thus, encouraging mothers to maintain favourable dietary habits for children in early childhood may lead to the formulation of favourable dietary habits.

It is difficult for many mothers to improve healthy eating habits during the busy postpartum child-rearing period. First, mothers raising small children have limited access to advice on improving their dietary quality. Although health centres provide dietary advice to parents when their children undergo health checkups, this advice tends to focus on food and feeding practices.[10] Second, mothers of older preschool children may have less time to prepare food and spend time eating with their children due to work.[11,12] However, improving dietary habits during pregnancy may be more effective than providing nutritional education during the busy period after birth. Pregnancy may be a teachable period to promote healthy eating because many women are concerned about the health of their babies during pregnancy and are in frequent contact with their healthcare providers.[13,14] Indeed, antenatal nutrition education improves nutritional knowledge and dietary diversity.[15] Furthermore, a varied diet during pregnancy may lead to broader taste acceptance in offspring, and prenatal and early postnatal exposure to flavours enhance the infant's enjoyment of that flavour in solid foods during weaning.[16]

However, evidence regarding the diet quality of mothers during pregnancy being associated with the diet quality of offspring is scarce. Additionally, examining which food group intake increases in mothers may be effective to improve the quality of the offspring's diet would provide useful information for nutrition education; however, the number of studies is limited. Maternal diet quality during pregnancy is associated with that of the offspring at 14 years of age,[17] and maternal dietary variety is positively associated with higher dietary scores in children aged 2–4 years.[18] However, these studies did not examine the relationship between the dietary components of mothers and their children in detail. In a small sample study, diet quality during pregnancy was associated with a 2-year-old child's diet quality, with postpartum diet quality acting as a mediating factor.[19] However, in addition to overall diet quality, only vegetables and fruits were selected to examine the association with the child's diet.[19]

Studies have analysed the relationship between maternal dietary patterns during pregnancy and the child's diet; however, the relationship between maternal and offspring food group intakes has not been evaluated.[20,21] In a study of infants, maternal sugary beverage consumption during pregnancy was associated with higher sugary beverage intake among their offspring at 2 years of age; however, this study did not evaluate the overall diet quality.[22] We, therefore, aimed to investigate the association between diet quality during pregnancy in mothers and offspring at 3 years of age. We also examined the relationship between the components of the maternal and offspring diet to improve nutritional education for pregnant women to improve dietary health and choices in their offspring.

Participants and methods

The Seiiku Boshi cohort

Our study was based on the Seiiku Boshi cohort study, a prospective hospital-based birth cohort study conducted at the National Center for Child Health and Development (NCCHD) in Tokyo. The study design, recruitment, and data collection have been described in detail elsewhere.[23,24] We invited 4,164 pregnant women to participate in the study, of whom 2,309 pregnant women submitted written consent forms at their first prenatal visit before 14 weeks of gestation between May 2010 and November 2013. A baseline survey was conducted at recruitment, and subsequent surveys were conducted in mid-to-late pregnancy and after delivery annually. Including cases with multiple births, 2,403 children were born to these pregnant women at NCCHD. From July 2014 to October 2016, a 36-month follow-up, scheduled according to each child's birth month, was conducted at the NCCHD.

Ethical approvals

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human participants were approved by the Institutional Review Board of the National Center for Child Health and Development (project number 417). Written informed consent was obtained from all participants.

Dietary intake

Maternal dietary intake was assessed using a self-administered food frequency questionnaire (FFQ) as part of a mid-to-late pregnancy survey. The FFQ consisted of 167 food and beverage items, with nine frequency categories and three portion size categories, which assessed the habitual consumption of the listed foods within the previous 2 months. Information on dietary supplements was not used to calculate the nutrient intake because of the lack of a reliable composition table in Japan. This questionnaire has been validated in adults[25] as well as in women in early and late pregnancy based on 3-day dietary records.[26–28] The intakes of energy, nutrients, and food groups were calculated using a food composition table developed for the FFQ based on the Standard Tables of Food Composition in Japan.[29]

Offspring dietary intake was assessed using the Brief-type self-administered diet history questionnaire for Japanese preschool children (BDHQ3y), which was developed to assess dietary intake during the preceding month for Japanese children aged 3–6 years.[30] This is a four-page, structured questionnaire with four sections: (1) intake frequency of 57 selected foods commonly consumed in Japan and non-alcoholic beverage items; (2) daily intake of rice, including the type of rice (refined, unrefined, or rice boiled with barley) and miso soup; (3) usual cooking methods; and (4) general dietary behaviour.

The BDHQ3y also collects information about the frequency of consumption of fortified food/supplements in the previous month but does not collect the names of the nutrients in the fortified food/supplement. Additionally, the questionnaire does not cover portion sizes of food consumed by the participants but rather assumes age-specific portion sizes of food and beverages, which have been calculated based on previous studies.[30,31] Estimates of the daily intake of food, energy, and selected nutrients were calculated using an ad hoc computer algorithm for the BDHQ3y,[30,31] using the nutrient composition chart of food included in the Standard Tables of Food Composition in Japan.[32]

Diet quality score

The Japanese Food Guide Spinning Top (JFGST) is based on the Dietary Guidelines for Japanese people and guides people on the types and amounts of food they should eat daily to promote health.[33] The Food Guide comprises five categories of dishes: grain dishes (rice, bread, and noodles); vegetable dishes (vegetables, mushrooms, potatoes, and seaweed); fish and meat dishes (meat, fish, eggs, and soybeans); milk (milk and milk products); fruits (fruit and 100% fruit juice); and snacks and beverages.[33]

JFGST reference values were created for the general population. Reference values for pregnant or nursing mothers have been proposed by the Japanese Ministry of Health, Labour and Welfare[34] by considering the additional energy and nutrients for pregnant and nursing mothers proposed in the Dietary Reference Intakes for Japanese. The JFGST reference values provided the recommended number of servings for each dish category for children under six years old, as created by the Tokyo Metropolitan Government.[35]

The diet quality score of adherence to the JFGST for the general population has been developed[36] and is associated with a lower risk of death from all causes and cardiovascular disease[36,37] among middle-aged to early elderly men and women. However, we applied several modifications which have been proposed to this method. First, we replaced the subscore for energy intake with the subscore for sodium intake. This was based on a previous amendment suggested for young women in Japan to identify more areas for dietary improvement among the weight-conscious age[38] in a population where excessive sodium intake,[39] as well as underweight and weight gain restrictions during pregnancy,[40] are important public health issues. The 10% tile value of sodium intake, adjusted for energy intake using the residual method, was used as the cut-off value for the sodium intake subscore. Second, as the intake levels of most micronutrients were below the dietary reference intake among pregnant women in Japan,[41] we did not penalise for exceeding servings of grains, meat and fish, and dairy products; thus, participants who exceeded the lower recommendation value of not only vegetables and fruits but also grains, meat, fish, and dairy products received a score of 10 for that category.[38] This method has been previously validated by comparing it to other methods of calculating diet quality[42] and has shown that a maternal balanced diet score is negatively associated with low birth weight risk.[43] The same amendments were conducted on the children's scores since current Japanese guidelines do not recommend using energy intake to evaluate the adequacy of energy intake among children (evaluation using a growth chart is recommended), and it is difficult to scientifically determine the upper limit for each food category for a growing child. Finally, the scores (0–10) of the seven components were summed to provide a modified JFGST score for pregnant mothers (JFGST-PM score) and children (JFGST-3y score) (Supplementary Table 1). The JFGST-PM and JFGST-3y scores range from 0 to 70, with higher scores indicating higher adherence to the current dietary guidelines. The summed score for the five food groups (grain dishes, vegetable dishes, fish and meat dishes, milk, and fruits), excluding snacks, beverages, and sodium, was calculated as a subscore ranging from 0 to 50.[44]

Covariates

Self-reported pre-pregnancy height and weight, weight gain during pregnancy, maternal age, sex of offspring, birth height and weight, smoking and drinking status during pregnancy, and history of childbirth were retrieved from medical records. The BDHQ3y also asks about current height, weight, and response date. If the child's data were missing, they were complemented with measurements obtained at the 36-month visit. We calculated the body mass index (BMI) from self-reported height and weight. Children were defined as overweight according to the criteria of the International Task Force on Obesity in Childhood using population reference data specific for age and sex for BMI.[45] Maternal sociodemographic data were obtained using questionnaires administered at enrolment and were categorised as follows: annual household income (<4 million yen, 4–6 million yen, 6–8 million yen, 8–10 million yen, 10–15 million yen, or >15 million yen, missing), maternal education (university/graduate school, technical college/two-year junior college, high school or less, missing), and employment status during pregnancy (housewife, part-time employee, self-employed, full-time employee, or other).

Statistical analysis

We analysed children, excluding those with either extremely low or high energy intake (< 1 percentile or over the 99th percentile), of the pairs that responded during both pregnancy and at 3 years of age. Our main focus was not only to determine whether maternal diet during pregnancy correlates with the diet of 3-year-old children, but also to provide information that could be referenced in nutrition education for mothers. For both of the new scoring methods, JFGST-PM and JFGST-3y, there is no clinically valid cut-off point for determining any risk. Therefore, participant characteristics and dietary intakes were compared to the JFGST-PM score categorised into quartiles (Q1, 13.93–40.35; Q2, 40.41–45.01; Q3, 45.05–49.82; Q4, 49.83–66.04) using a linear-by-linear test for trend.

Next, associations between the JFGST-PM and JFGST-3y total scores, as well as between the JFGST-PM five-dish group score and the JFGST-3y five-dish group score, and each component score of the mother and offspring, were tested using linear regressions with offspring score as the dependent variable and maternal score categorised in quartiles as independent

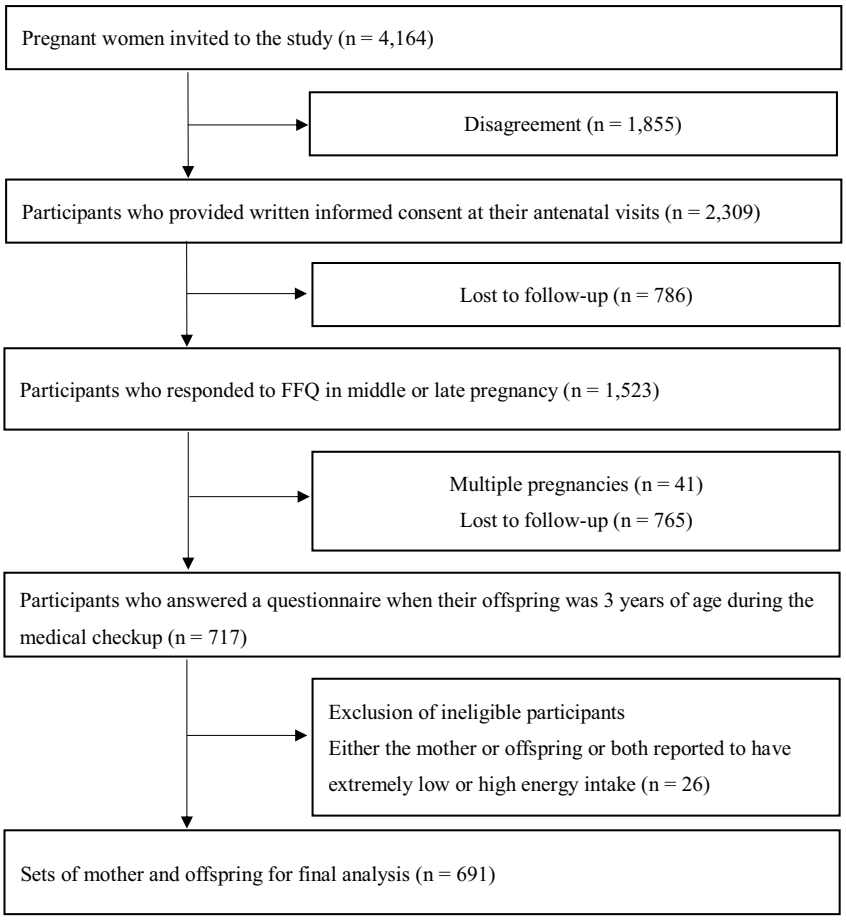

Fig. 1. Participants flow chart for the analytic sample.

variables. Indicators that could not be divided into quartiles due to the distribution of scores were divided as follows: second quantile for fish and meat dishes, tertiles for milk, and snacks and beverages. The adjusted models included the following potential confounders: sex of offspring, maternal age at birth, mother's educational history, and annual household income. Missing values were assigned to a "missing" category for each of these covariate variables. All statistical analyses were performed using Stata version 18.0 (Stata Corp. College Station, Texas). Two-sided P-values were presented.

Results

Of the 4,164 women who were invited to the study, 2,309 women provided written informed consent at their antenatal visits, 1,523 responded to the FFQ in middle or late pregnancy. Of these, 43 were multiple pregnancies, and 717 mothers of singletons answered the questionnaire when their offspring were 3 years of age during the medical checkup. Twenty-six results where the child, mother, or both reported extremely low or high energy intake (< 1 percentile, below 553 kcal in pregnant mothers or 803 kcal in offspring; or over the 99th percentile, more than 3,632 kcal in pregnant mothers or 2,705 kcal in offspring) were excluded.[23] In total, 691 dyads of mothers and 3-year-old offspring were included in the analysis (Fig. 1).

A comparison of mothers included in the analysis (n = 691) with those lost to follow-up, excluding extremely low or high energy intake (excluding under the first percentile or over the 99th percentile, n = 749) among responders to the FFQ during pregnancy (n = 1,523), showed that more of those included were older (36.5 (SD 4.2) years vs. 35.2 (SD 4.4) years, $P < 0.001$) and had their first child (65.8% vs. 56.0%, $P < 0.001$). However, fewer women were underweight before pregnancy (18.2% vs. 24.5%, $P = 0.034$) and had less weight gain during pregnancy (9.6 (SD 3.6) kg vs. 10.1 (SD 3.7) kg, $P = 0.019$). The prevalence was similar for both annual household income and educational history. There were no significant differences in the intake of dish categories other than vegetable dishes (3.8 (SD 1.9) servings vs. 3.5 (SD 2.1) servings, $P = 0.045$) (Supplementary Table 2 and Table 1).

The overweight rate among offspring was 8.6%, whereas the rate for maternal pre-pregnancy overweight was 4.8%. Sixty-two percent of mothers held a university/graduate school degree (Table 1).

The mean JFGST scores for mothers and offspring were 44.9 (SD 7.4) and 56.3 (SD 5.8), respectively. Of the maternal intakes of dish categories, the average number of servings in the grain dishes, vegetable dishes, and fruits were below the recommended number of servings for pregnancy, and the energy intake from snacks and beverages was above the recommended amount (Supplementary Table 3). Offspring diet quality score and each dish category score of vegetable dishes, fish and meat dishes, milk, and fruits were higher for higher quartiles of the maternal diet quality score, whereas the score of sodium was

Table 1. Characteristics of the study population according to the maternal diet quality score in quartiles

			JFGST-PM score in quartiles							
	All		Q1 (n = 173)		Q2 (n = 173)		Q3 (n = 173)		Q4 (n = 172)	
	Mean or No.	SD or %	Mean or No.	SD or %	Mean or No.	SD or %	Mean or No.	SD or %	Mean or No.	SD or %
Offspring characteristic										
Gender										
Boys	371	53.7	106	61.3	83	48.0	89	51.4	93	54.1
Girls	320	46.3	67	38.7	90	52.0	84	48.6	79	45.9
Height (cm)	92.2	3.8	92.4	3.7	92.1	3.7	92.3	4.3	92.2	3.6
BMI (kg/m^2)	15.9	1.4	15.9	1.3	15.8	1.3	16.1	1.6	15.8	1.3
Overweight[a]	59.0	8.6	18.0	10.5	13.0	7.5	18.0	10.4	10.0	5.8
Birth height (cm)	49.3	2.6	49.2	2.5	49.3	2.7	49.8	2.0	49.1	3.1
Birth weight (g)	3006	435	3008	464	3008	412	3050	394	2960	465
Maternal characteristic										
Age at birth (y)	36.5	4.2	36.6	4.4	36.2	4.1	36.7	3.9	36.7	4.3
Pre-pregnancy BMI (kg/m^2)	20.5	2.6	20.8	2.8	20.6	2.4	20.4	2.6	20.4	2.6
Pre-pregnancy BMI category										
<18.5 kg/m^2	125	18.2	28	16.5	31	18.0	28	16.4	38	22.1
18.5–24.9 kg/m^2	527	76.9	129	75.9	137	79.7	134	78.4	127	73.8
≥25 kg/m^2	33	4.8	13	7.6	4	2.3	9	5.3	7	4.1
Missing	6		3		1		2		0	
Gestational weight gain (kg)	9.6	3.6	9.4	3.8	9.6	3.8	10.0	3.4	9.5	3.4
History of childbirth										
First	455	65.8	98	56.6	117	67.6	121	69.9	119	69.2
Parity	236	34.2	75	43.4	56	32.4	52	30.1	53	30.8
Educational history										
High school or less	44	6.6	11	6.8	13	7.7	9	5.4	11	6.6
Technical college/two-year junior college	208	31.3	50	30.7	51	30.0	54	32.5	53	31.9
University/graduate school	413	62.1	102	62.6	106	62.4	103	62.1	102	61.5
Missing	26		10		3		7		6	
Employment status during pregnancy										
Housewife	273	41.1	66	40.7	84	49.7	60	35.7	63	38.2
Part-time employee	93	14.0	22	13.6	24	14.2	20	11.9	27	16.4
Self-employed	29	4.4	6	3.7	7	4.1	11	6.5	5	3.0
Full-time employee	247	37.2	62	38.3	49	29.0	71	42.3	65	39.4
Other	22	3.3	6	3.7	5	3.0	6	3.6	5	3.0
Missing	27		11		4		5		7	
Annual household income (yen/year)										
<4 million	48	7.6	15	9.6	14	8.7	13	8.2	6	3.8
4 million to less than 6 million	93	14.6	22	14.1	26	16.1	28	17.7	17	10.6
6 million to less than 8 million	129	20.3	36	23.1	32	19.9	26	16.5	35	21.9
8 million to less than 10 million	123	19.4	30	19.2	31	19.3	29	18.4	33	20.6
10 million to less than 15 million	173	27.2	33	21.2	42	26.1	47	29.7	51	31.9
>15 million	69	10.9	20	12.8	16	9.9	15	9.5	18	11.3
Missing	56		17		12		15		12	
Smoking status during pregnancy (yes)	6	0.9	1	0.6	3	1.7	0	0.0	2	1.2
Drinking status during pregnancy (yes)	11	1.6	3	1.7	2	1.2	6	3.5	0	0.0

JFGST-PM score; scores on the adherence to the Japanese Food Guide Spinning Top for pregnant mothers; BMI, body mass index.
[a]Classification by gender and age-specific cut-off points advocated by The International Obesity Task Force.

lower for higher quartiles of the maternal diet quality score (Table 2). For the intake of dish categories, the number of servings of vegetable dishes and fruits was higher in the higher quartiles of maternal diet quality scores (Table 2).

The mean energy intake for mothers and offspring was 1,619 (SD 507) kcal and 1,403 (SD 337) kcal, respectively. Maternal intake of energy and nutrients other than carbohydrates and dietary fibre was higher in the higher quartiles of the maternal diet quality score (Supplementary Table 4). Offspring energy, protein, retinol equivalent, vitamin B1, vitamin B2, vitamin C, calcium, ferric, dietary fibre, and potassium intakes were higher in the higher quartiles of maternal diet quality scores (Table 3).

Table 4 shows an increase in the average offspring diet quality total score and five-dish group scores across the high quartiles of maternal diet quality scores (P for trend <0.001). After adjustment for confounding variables, the mean increments of diet quality score of offspring for total score in the third and fourth quartile categories were 1.54 (0.34–2.73) and 1.22 (0.03–2.42) compared to the first category of maternal diet quality score. Similarly, adjusted mean increments of diet quality score of offspring for five-dish groups score in the third and fourth quartiles were 1.45 (0.39–2.52) and 1.65 (0.58–2.72) compared to the first category of maternal diet quality score. Maternal vegetable dishes, fish and meat dishes, milk, fruits, and

Table 2. Distribution of the scores on the adherence to the Japanese Food Guide Spinning Top for 3-year-old offspring and the intakes of each dish category according to the maternal diet quality score in quartiles

				JFGST-PM score in quartiles								
	Recommended No. of servings in the JFGST	All		Q1 (n = 173)		Q2 (n = 173)		Q3 (n = 173)		Q4 (n = 172)		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P^a
JFGST-3y score												
Total (0–70)		56.3	5.8	55.8	6.6	55.4	6.0	57.2	5.0	57.0	5.1	0.005
Five-dish groups (0–50)		40.0	5.1	39.2	5.8	39.1	5.4	40.7	4.5	40.9	4.5	<0.001
Grain dishes (0–10)		8.2	1.6	8.3	1.6	8.2	1.7	8.1	1.6	8.1	1.6	0.107
Vegetable dishes (0–10)		5.2	2.3	4.9	2.4	5.1	2.4	5.2	2.3	5.4	2.1	0.023
Fish and meat dishes (0–10)		9.2	1.5	9.0	1.7	9.1	1.5	9.3	1.3	9.3	1.3	0.028
Milk (0–10)		8.9	2.3	8.8	2.3	8.3	2.8	9.2	2.1	9.2	1.9	0.006
Fruits (0–10)		8.6	2.5	8.2	2.9	8.4	2.7	8.9	2.1	8.9	2.2	0.004
Snacks and beverages (0–10)		9.4	1.6	9.4	1.6	9.1	2.0	9.6	1.3	9.4	1.5	0.368
Sodium (0–10)		7.0	2.1	7.1	2.3	7.2	2.1	6.9	2.2	6.7	2.1	0.020
Intakes of dish categories (/day)												
Grain dishes (serving)	3–4	2.1	0.6	2.2	0.6	2.2	0.6	2.1	0.6	2.1	0.5	0.147
Vegetable dishes (serving)	4	1.8	0.9	1.7	0.9	1.8	0.9	1.9	0.8	2.0	1.0	0.018
Fish and meat dishes (serving)	3	2.9	1.0	2.8	1.0	2.8	1.0	2.9	0.9	2.9	0.9	0.204
Milk (serving)	2	2.4	1.4	2.4	1.5	2.3	1.5	2.5	1.2	2.6	1.4	0.145
Fruits (serving)	1–2	0.7	0.5	0.6	0.5	0.7	0.5	0.7	0.4	0.8	0.5	0.002
Energy intake from snacks and beverages (kcal)	≤200	142	79	146	76	150	87	136	69	137	83	0.146
Energy-adjusted Sodium intake (mg)	–	3635	680	3599	708	3575	673	3650	688	3717	647	0.065

JFGST, Japanese Food Guide Spinning Top; JFGST-PM score, scores on the adherence to the JFGST for pregnant mothers; JFGST-3y score, scores on the adherence to the JFGST for 3-year-old.
[a]P values are based on linear-by-linear test for trend.

Table 3. Energy and nutritional intakes of 3-year-old offspring according to the maternal diet quality score in quartiles

			JFGST-PM score in quartiles								
	All		Q1 (n = 173)		Q2 (n = 173)		Q3 (n = 173)		Q4 (n = 172)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P^a
Energy (kcal)	1403	337	1337	314	1406	331	1445	352	1423	344	0.010
Protein (%E)	15.0	2.1	14.8	2.0	14.7	2.3	15.1	2.0	15.3	2.0	0.011
Fat (%E)	28.6	4.8	28.7	4.6	28.6	5.2	28.7	4.9	28.5	4.6	0.773
Carbohydrate (%E)	55.3	6.0	55.3	5.8	55.6	6.5	55.2	6.0	55.2	5.7	0.723
Retinol equivalent (μg/1000kcal)	357	144	332	127	348	140	369	149	380	155	0.001
Vitamin B1 (mg/1000kcal)	0.41	0.07	0.40	0.06	0.41	0.07	0.41	0.06	0.42	0.07	0.013
Vitamin B2 (mg/1000kcal)	0.73	0.16	0.72	0.16	0.70	0.17	0.74	0.15	0.75	0.15	0.012
Vitamin C (mg/1000kcal)	53.6	22.2	49.7	22.9	52.8	23.4	54.5	20.4	57.5	21.4	0.001
Calcium (mg/1000kcal)	429	125	419	130	411	129	437	117	449	122	0.006
Ferric (mg/1000kcal)	3.9	0.8	3.8	0.8	3.9	0.8	3.9	0.7	4.0	0.8	0.002
Dietary fibre (g/1000kcal)	6.4	1.6	6.1	1.5	6.3	1.6	6.4	1.4	6.7	1.7	0.002
Saturated fatty acids (%E)	9.7	2.4	9.8	2.5	9.6	2.6	9.7	2.1	9.7	2.3	0.761
Sodium (g/1000kcal)	6.6	1.3	6.6	1.4	6.5	1.2	6.6	1.2	6.8	1.2	0.218
Potassium (mg/1000kcal)	1272	262	1231	254	1245	270	1288	249	1323	267	<0.001

JFGST-PM score; scores on the adherence to the Japanese Food Guide Spinning Top for pregnant mothers.
[a]P values are based on linear-by-linear test for trend.

sodium scores correlated with offspring scores (P for trend <0.05, respectively). In particular, vegetable dishes scored higher in all quartiles compared to the lowest quartile (2nd, 0.69 (0.21–1.17); 3rd, 0.97 (0.50–1.45); and 4th, 1.36 (0.88–1.83)).

Discussion

Analyses based on 691 mother–offspring pairs who participated in the Seiiku Boshi cohort study showed that a high diet quality score during pregnancy was associated with that of 3-year-old offspring. Of the components of the diet quality score, maternal vegetable dishes, fish and meat dishes, milk, fruits, and sodium were associated with the offspring components of the diet quality score, with vegetable dishes being the most strongly associated. These results suggest that improving the overall quality of the maternal diet during pregnancy, especially by increasing vegetable intake, can be one of the ways to improve the quality of the offspring's diet.

Table 4. Unadjusted and adjusted differences in mean increments in the diet quality score of offspring according to the maternal diet quality score in quartiles[a]

	Unadjusted				Adjusted for covariables			
	Increment	95% CI		*P*	Increment	95% CI		*P*[b]
JFGST-3y for total score (0–70) in quartiles of JFGST-PM for total score								
Quartile 1 (13.93–40.35)	Ref			–	Ref			–
Quartile 2 (40.41–45.01)	−0.37	−1.58	0.83	0.544	−0.12	−1.32	1.08	0.843
Quartile 3 (45.05–49.82)	1.44	0.23	2.64	0.020	1.54	0.34	2.73	0.012
Quartile 4 (49.83–66.04)	1.21	0.01	2.42	0.049	1.22	0.03	2.42	0.045
P for trend				<0.001				0.006
JFGST-3y for five-dish groups score (0–50) in quartiles of JFGST-PM for five-dish groups score								
Quartile 1 (3.93–27.70)	Ref			–	Ref			–
Quartile 2 (27.72–33.26)	1.11	0.03	2.19	0.044	1.06	0.00	2.13	0.051
Quartile 3 (33.27–37.82)	1.46	0.38	2.53	0.008	1.45	0.39	2.52	0.008
Quartile 4 (37.83–50.00)	1.87	0.79	2.95	0.001	1.65	0.58	2.72	0.002
P for trend				0.001				0.002
Grain dishes (0–10) in quartiles of maternal grain dishes score								
Quartile 1 (1.05–4.245)	Ref			–	Ref			–
Quartile 2 (4.25–5.642)	0.14	−0.20	0.48	0.428	0.18	−0.17	0.52	0.313
Quartile 3 (5.643–6.908)	0.02	−0.32	0.36	0.918	0.02	−0.32	0.36	0.893
Quartile 4 (6.909–10.00)	−0.18	−0.52	0.16	0.306	−0.14	−0.49	0.20	0.410
P for trend				0.235				0.291
Vegetable dishes score (0–10) in quartiles of maternal vegetable dishes score								
Quartile 1 (0–4.11)	Ref			–	Ref			–
Quartile 2 (4.12–5.81)	0.70	0.23	1.18	0.004	0.69	0.21	1.17	0.005
Quartile 3 (5.82–7.81)	0.96	0.49	1.44	<0.001	0.97	0.50	1.45	<0.001
Quartile 4 (7.88–10.00)	1.37	0.90	1.85	<0.001	1.36	0.88	1.83	<0.001
P for trend				<0.001				<0.001
Fish and meat dishes (0–10) in 2-quantile of maternal fish and meat dishes score								
Two-quantile 1 (0–7.58)	Ref			–	Ref			–
Two-quantile 2 (7.63–10.00)	0.35	0.10	0.60	0.007	0.36	0.10	0.61	0.007
Milk score (0–10) in tertiles of maternal milk score								
Tertile 1 (0–5.08)	Ref			–	Ref			–
Tertile 2 (5.13–8.73)	0.44	−0.05	0.93	0.079	0.41	−0.08	0.90	0.100
Tertile 3 (8.75–10.00)	0.55	0.13	0.98	0.010	0.49	0.07	0.91	0.022
P for trend				0.013				0.028
Fruits score (0–10) in quartiles of maternal fruits score								
Quartile 1 (0–2.439)	Ref			–	Ref			–
Quartile 2 (2.442–4.26)	0.50	−0.02	1.02	0.058	0.48	−0.04	1.00	0.068
Quartile 3 (4.27–6.868)	0.85	0.33	1.37	0.001	0.71	0.18	1.23	0.008
Quartile 4 (6.874–10)	0.95	0.43	1.47	<0.001	0.93	0.41	1.45	<0.001
P for trend				<0.001				<0.001
Snacks and beverages score (0–10) in tertiles of maternal snacks and beverages score								
Tertile 1 (0–3.92)	Ref			–	Ref			–
Tertile 2 (3.96–9.39)	−0.04	−0.39	0.30	0.806	−0.09	−0.44	0.26	0.613
Tertile 3 (9.40–10)	0.15	−0.14	0.45	0.310	0.13	−0.17	0.43	0.402
P for trend				0.240				0.300
Sodium score (0–10) in quartiles of maternal sodium score								
Quartile 1 (0–3.37)	Ref			–	Ref			–
Quartile 2 (3.39–5.7491)	0.23	−0.22	0.68	0.317	0.18	−0.28	0.63	0.452
Quartile 3 (5.7494–7.78)	0.37	−0.08	0.82	0.110	0.39	−0.07	0.84	0.098
Quartile 4 (7.81–10.00)	0.51	0.05	0.96	0.028	0.48	0.03	0.94	0.038
P for trend				0.023				0.024

JFGST, Japanese Food Guide Spinning Top; JFGST-PM score, scores on the adherence to the JFGST for pregnant mothers; JFGST-3y score, scores on the adherence to the JFGST for 3-year-old; CI, confidence interval.
[a]The group of the lowest quartile was used as a reference for each pairwise comparison.
[b]Adjusted for offspring sex, gestational age, mother's educational history, and annual household income.

Previous studies in other countries and at different offspring ages have confirmed that diet quality during pregnancy has a long-term effect on both mother and offspring. A large national birth cohort in Norway showed that maternal diet quality during pregnancy is associated with the diet quality of offspring at 14 years of age.[17] A European birth cohort study showed that maternal dietary variety, consisting of five food group scores, was positively associated with that of a higher score of children aged 2–4 years.[18] A prospective study of 52 mother–child dyads in Australia found an association between pregnancy and

a 2-year-old child's diet quality.[19] A study of 1,171 pairs in Canada showed that maternal sugary beverage consumption during pregnancy was associated with higher sugary beverage intake among offspring at age two.[22] The novelty of our study lies in that we showed, in a prospective design with a large population, that the quality of the mother's diet during pregnancy affects the diet quality of their 3-year-old offspring, which is the formative period of eating habits.

We examined which dish categories mothers could increase to affect the dish categories of their offspring's diets. We showed that the establishment of fish and meat, milk, fruits, and especially vegetable intake and decreasing sodium intake during the gestational period may contribute to improving offspring diet quality. Women do not appear to consume a wide variety of nutritious foods during pregnancy[41,46]; therefore, expert guidance to build an optimal diet during pregnancy is important.

We also observed that vegetables showed the lowest scores among all categories for offspring and that many mothers, even those with the highest overall diet quality score, did not meet the recommended values for vegetables. Thus, increasing vegetable intake among mothers may be a promising intervention to improve maternal and offspring diet quality. The strong association observed between maternal and offspring vegetable intake is likely due to two factors: either maternal vegetable intake directly influences the offspring's personal preference, or indirectly, the offspring are exposed to vegetables through the mother's postnatal diet. As shown in a previous small study of 52 mother-infant dyads, vegetable intake during pregnancy is strongly correlated with postnatal vegetable intake, which acts as a mediator of the association with offspring intake, suggesting that the indirect effect is stronger than the direct effect.[19] Additionally, limited but consistent evidence has shown that foetal exposure to flavours of certain vegetables, such as carrots and garlic, contained in the maternal diet and transmitted through the amniotic fluid increases the acceptance of the exposed flavour during infancy and potentially during childhood.[16] Similar findings have been reported for maternal fruit and vegetable variety.[19]

In this study, maternal sodium score positively correlated with offspring sodium score, whereas the group with a higher quartile of overall maternal diet quality score had lower offspring sodium scores. Our findings are consistent with a systematic review of Japanese studies in which a higher frequency of consumption of meals consisting of grain, fish, meat, and vegetable dishes was related to not only a higher intake of energy, protein, vitamins, and minerals, and higher odds of meeting the Dietary Reference Intakes for Japanese,[47] but also a higher intake of sodium. This may be a unique cultural problem in Japan because Japanese diets tend to contain high levels of sodium.[39] Thus, when nutritional education is provided to mothers to increase their intake of fish and meat dishes, and vegetable dishes, it is also important to educate them on low-sodium cooking methods.

Unlike in previous studies,[22] the maternal scores for snacks and beverages during pregnancy were not associated with the offspring scores in our study. This may be due to the current criteria for snacks being less strict in Japan compared to other countries where the evaluation criteria are set at "less than 200 kcal" for both parents and children, leading to many children getting a score of 10 for snacks in this study. The average intakes of snacks and beverages were 252 kcal for mothers and 142 kcal for children. Thus, using stricter criteria such as portion size may better differentiate children and lead to an association with maternal intake.

In the present study, no association was found between the maternal diet quality score and children's energy intake from fat, saturated fatty acids, and carbohydrates. This may be partly because the categories strongly associated with the maternal diet quality score were vegetable dishes and fruits, which had a low impact on fat and carbohydrate intake. In contrast, according to the studies that assessed adherence to the JFGST in young women, higher dietary adherence was associated with higher intake of protein, carbohydrates, vitamins, and minerals and lower intake of total and saturated fat.[38,48] Since the JFGST expresses diet quality in terms of dish units per category and does not consider food choices within food groups, the dietary characteristics reflected in scores may vary according to the participants' food choices. The mean energy percentages of fat and saturated fatty acids for the children in this study were 28.6% and 9.7%, respectively, which were lower than the target amounts in the Dietary Reference Intakes (20–30% and <10%, respectively)[49]; therefore, these were not high on the priority list as restriction targets. However, to avoid excessive intake of fat and saturated fatty acids, it is advisable to avoid meat as the only main dish and choose low-fat dairy products.

In our study, the absolute mean difference in JFGST-3y scores among the quartile groups of JFGST-PM scores was relatively small compared with that in previous studies on diet quality scores conducted among adults and older children. This may be attributed to the fact that the proportion size was small in Preschool children. As it has been reported that unfavourable eating habits such as increased intake of free sugars, and lower fruit and vegetable intakes tend to be acquired around 1.5–3 years of age,[4] and as portion size increases with age, we believe the absolute difference in scores observed in this study may underestimate its true long-term effect.

Our study suggests that improving the dietary habits of pregnant women can have benefits not only for the women themselves but also for their offspring. Currently, individualised nutrition education for pregnant women is mainly provided to those who have developed specific nutritional problems, such as gestational hypertension, obesity, or anaemia, which are eligible for medical reimbursement in Japan. However, considering that a mother's eating habits can influence the long-term dietary choices of her children, it may be beneficial to provide nutrition education even to those without existing nutritional problems. Since pregnant women have regular healthcare visits during their pregnancy, there is an opportunity to incorporate nutrition education from a registered dietitian alongside medical advice from an obstetrician. Specifically, our study highlights the importance of increasing intake of fish and meat, milk, fruits, and especially vegetables during pregnancy while also emphasising the need for education on reducing sodium in cooking. Given that adopting these dietary changes may require more than a single education session, it would be beneficial to provide

ongoing instruction during antenatal visits and set short-term goals through regular follow-ups until these habits become established.

The strengths of our study include its prospective design, use of diet quality rather than focusing on single nutrients or foods, and utilisation of dietary and food frequency questionnaires validated for pregnant women[26–28] and children.[30,31] However, this study had some limitations. First, our diet quality index did not consider energy intake or the upper limit of each food group[38] and could have led to an overestimation of diet quality if high energy intake and overeating were prevalent. However, the prevalence of such participants was likely low, as the average number of servings in all categories was below the recommended number, with the exception of snacks and beverages for pregnant women and milk for preschool children. The proportion of overweight and obese children was also very low among both pregnant women and preschool children in our population.[49] In the previous studies, the methods for calculating diet quality scores were adjusted to align with the characteristics of the participants.[36–38,44] Further research is needed to assess the suitability of the calculation method employed in this study for pregnant women and their offspring. Second, we utilised a diet quality score that did not consider the quality of foods within a food group, such as red meat among meats, or whole grains among cereals. Since the JFGST itself does not consider the quality of foods, it is unclear whether the same results would be obtained if dietary quality were assessed using the methods used in other countries. Third, the dietary questionnaires used for the offspring diet survey and maternal dietary questionnaire during pregnancy were created independently and had different question formats, which may have underestimated parent-offspring correlations. Fourth, we did not make adjustments for physical activity, smoking, alcohol intake during pregnancy, or the introduction of foods, factors that have been considered in other studies.[17,18] However, even in these studies, the effects of these covariates were found to be relatively small. Fifth, this study was conducted at a single perinatal centre in an urban area that generally had more pregnant women of advanced age,[50] higher socioeconomic status, and more pregnant women with complications. These differences may have led to a higher diet quality than in the general population but may also have contributed to the higher accuracy of responses to both maternal and offspring dietary questionnaires. Although a nationwide survey reported a positive correlation between annual household income and vegetable intake,[51] the number of servings of vegetable dishes in this study was similar to that observed in another nationwide birth cohort study.[43] Lastly, because pre-pregnancy intake data was not collected in this study, we cannot demonstrate changes in dietary intake specifically due to pregnancy. However, according to a nationwide birth cohort study in Japan, food intake did not significantly differ from pre-pregnancy to pregnancy, with no notable improvement in diet observed after pregnancy.[41]

In conclusion, a high score of diet quality during pregnancy in mothers affects that of their 3-year-old offspring. Increasing maternal fish and meat, milk, fruits, and especially vegetable intake and decreasing sodium intake from the gestational period can be one of the ways to improve the quality of the offspring's diet. These results suggest the usefulness of nutrition education to improve maternal diet quality during pregnancy when there are more opportunities to interact with healthcare providers.

Supplementary material

The supplementary material for this article can be found at https://doi.org/10.1017/jns.2024.24

Acknowledgements

We are deeply grateful to all participants in this study and to the hospital staff for their cooperation.

Financial support

This work was partially supported by grants from the Research Development Grant for Child Health and Development of the National Center for Child Health and Development (25–4) and by grants from the Children and Families Agency (23DA0101). The funders had no role in the study design, data collection and analysis, decision to publish, or manuscript preparation.

Competing interests

The authors declare none.

Authorship

The authors' contributions were as follows: Y.T. contributed to the conceptualisation of the study question, conducted the statistical analysis, interpreted the data, prepared the first draft of the manuscript, and had primary responsibility for the final content of the manuscript; K.I. contributed to the conceptualisation of the study question, interpreted the data, and provided input into the final draft of the manuscript; A.P. contributed to the statistical analysis, interpreted the data, and provided input into the final draft of the manuscript; H.T., K.O., M.K., R.H., and T.F. contributed to the concept and design of the survey, coordination of the fieldwork, data collection and management, and provided input into the final draft of the manuscript; N.M. contributed to the concept and design of the survey, conceptualised the study question, interpreted the data, and provided input into the final draft of the manuscript. All authors were involved in writing the paper and provided their final approval for the publication of the submitted version.

References

1. Kaikkonen JE, Mikkilä V, Raitakari OT. Role of childhood food patterns on adult cardiovascular disease risk. *Curr Atheroscler Rep.* 2014;16:443.
2. Mikkilä V, Räsänen L, Raitakari OT, *et al.* Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study. *Br J Nutr.* 2005;93:923–931.
3. Bourke M, Whittaker PJ, Verma A. Are dietary interventions effective at increasing fruit and vegetable consumption among overweight children? A systematic review. *J Epidemiol Community Health.* 2014; 68:485–490.

4. Emmett PM, Jones LR. Diet, growth, and obesity development throughout childhood in the Avon longitudinal study of parents and children. *Nutr Rev.* 2015;73:175–206.
5. Moumin NA, Netting MJ, Golley RK, *et al.* Does food intake of australian toddlers 12–24 months align with recommendations: findings from the Australian feeding infants and toddlers study (OzFITS) 2021. *Nutrients.* 2022;14:2890.
6. Bandura A. Social cognitive theory: an agentic perspective. *Annu Rev Psychol.* 2001;52:1–26.
7. Arredondo EM, Ayala GX, Soto S, *et al.* Latina mothers as agents of change in children's eating habits: findings from the randomized controlled trial entre familia: Reflejos de Salud. *Int J Behav Nutr Phys Act.* 2018;15:95.
8. Pearson N, Biddle SJ, Gorely T. Family correlates of fruit and vegetable consumption in children and adolescents: a systematic review. *Public Health Nutr.* 2009;12:267–283.
9. Tada Y, Tomata Y, Sunami A, *et al.* Examining the relationship between vegetable intake of mothers and that of their children: a cross-sectional study of 10- to 12-year-old schoolchildren in Japan. *Public Health Nutr.* 2015;18:3166–3171.
10. Holmberg Fagerlund B, Helseth S, Glavin K. Parental experience of counselling about food and feeding practices at the child health centre: a qualitative study. *J Clin Nurs.* 2019;28:1653–1663.
11. Möser A, Chen SE, Jilcott SB, *et al.* Associations between maternal employment and time spent in nutrition-related behaviours among German children and mothers. *Public Health Nutr.* 2012;15:1256–1261.
12. Household Statistics Office Ministry of Health, Labour and Welfare. *Results of the 15th Longitudinal Survey of Newborns in the 21st Century (2001 Cohort) and the 6th Longitudinal Survey of Newborns in the 21st Century (2010 Cohort).* Chiyoda, Tokyo: Ministry of Health, Labour and Welfare; 2017.
13. Phelan S. Pregnancy: a "teachable moment" for weight control and obesity prevention. *Am J Obstet Gynecol.* 2010;202:135.e131–138.
14. Paterson H, Hay-Smith E, Treharne G. Women's experiences of changes in eating during pregnancy: a qualitative study in Dunedin, New Zealand. *N Z Coll Midwives.* 2016;52:5–11.
15. Katenga-Kaunda LZ, Kamudoni PR, Holmboe-Ottesen G, *et al.* Enhancing nutrition knowledge and dietary diversity among rural pregnant women in Malawi: a randomized controlled trial. *BMC Pregnancy Childbirth.* 2021;21:644.
16. Spahn JM, Callahan EH, Spill MK, *et al.* Influence of maternal diet on flavor transfer to amniotic fluid and breast milk and children's responses: a systematic review. *Am J Clin Nutr.* 2019;109:1003s–1026s.
17. Bjerregaard AA, Halldorsson TI, Tetens I, *et al.* Mother's dietary quality during pregnancy and offspring's dietary quality in adolescence: Follow-up from a national birth cohort study of 19,582 mother-offspring pairs. *PLoS Med.* 2019;16:e1002911.
18. Jones L, Moschonis G, Oliveira A, *et al.* The influence of early feeding practices on healthy diet variety score among pre-school children in four European birth cohorts. *Public Health Nutr.* 2015;18:1774–1784.
19. Ashman AM, Collins CE, Hure AJ, *et al.* Maternal diet during early childhood, but not pregnancy, predicts diet quality and fruit and vegetable acceptance in offspring. *Matern Child Nutr.* 2016;12:579–590.
20. Lioret S, Cameron AJ, McNaughton SA, *et al.* Association between maternal education and diet of children at 9 months is partially explained by mothers' diet. *Matern Child Nutr.* 2015;11:936–947.
21. Okubo H, Miyake Y, Sasaki S, *et al.* 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. *Matern Child Nutr.* 2014;10:213–225.
22. Limbachia J, Desai D, Abdalla N, *et al.* The association of maternal sugary beverage consumption during pregnancy and the early years with childhood sugary beverage consumption. *Can J Public Health.* 2023;114:231–240.
23. Ogawa K, Morisaki N, Kobayashi M, *et al.* Maternal vegetable intake in early pregnancy and wheeze in offspring at the age of 2 years. *Eur J Clin Nutr.* 2018;72:761–771.
24. Ando E, Morisaki N, Asakura K, *et al.* Association between dietary intake and serum biomarkers of long-chain PUFA in Japanese preschool children. *Public Health Nutr.* 2020;24:1–11.
25. Tsugane S, Kobayashi M, Sasaki S. Validity of the self-administered food frequency questionnaire used in the 5-year follow-up survey of the JPHC study cohort I: comparison with dietary records for main nutrients. *J Epidemiol.* 2003;13:51–56.
26. Ogawa K, Jwa SC, Kobayashi M, *et al.* Validation of a food frequency questionnaire for Japanese pregnant women with and without nausea and vomiting in early pregnancy. *J Epidemiol.* 2017;27:201–208.
27. Kobayashi M, Jwa SC, Ogawa K, *et al.* Validity of a food frequency questionnaire to estimate long-chain polyunsaturated fatty acid intake among Japanese women in early and late pregnancy. *J Epidemiol.* 2017;27:30–35.
28. Jwa SC, Ogawa K, Kobayashi M, *et al.* Validation of a food-frequency questionnaire for assessing vitamin intake of Japanese women in early and late pregnancy with and without nausea and vomiting. *J Nutr Sci.* 2016;5:e27.
29. Ministry of Education, Culture, Sports, Science and Technology of Japan. *Standard Tables of Food Composition in Japan 2020 (Eighth Revised Version).* Chiyoda, Tokyo: Ministry of Education, Culture, Sports, Science and Technology of Japan; 2020.
30. Asakura K, Haga M, Sasaki S. Relative validity and reproducibility of a brief-type self-administered diet history questionnaire for Japanese children aged 3–6 years: application of a questionnaire established for adults in preschool children. *J Epidemiol.* 2015;25:341–350.
31. Asakura K, Haga M, Adachi M, *et al.* Estimation of food portion sizes frequently consumed by children 3–6 years old in Japan. *J Nutr Sci Vitaminol (Tokyo).* 2014;60:387–396.
32. Ministry of Education, Culture, Sports, Science and Technology. *Standard Tables of Food Composition in Japan (Fifth Revised and Enlarged Edition -2010-).* Chiyoda, Tokyo: Ministry of Education, Culture, Sports, Science and Technology; 2010.
33. Yoshiike N, Hayashi F, Takemi Y, *et al.* A new food guide in Japan: the Japanese food guide spinning top. *Nutr Rev.* 2007;65:149–154.
34. Ministry of Health, Labour and Welfare, Japan. *Starting Before Pregnancy, Dietary Guidelines for Pregnant Women.* Chiyoda, Tokyo: Ministry of Health, Labour and Welfare, Japan; 2021.
35. Tokyo Metropolitan Government. *Guidance Manual of Dietary Guidelines for Preschool Children in Tokyo (in Japanese).* Shinjuku City: Tokyo Metropolitan Government; 2006.
36. Kurotani K, Akter S, Kashino I, *et al.* Quality of diet and mortality among Japanese men and women: Japan Public Health Center based prospective study. *BMJ.* 2016;352:i1209.
37. Kurotani K, Honjo K, Nakaya T, *et al.* Diet quality affects the association between census-based neighborhood deprivation and all-cause mortality in Japanese men and women: the Japan public health center-based prospective study. *Nutrients.* 2019;11:2194.
38. Kuriyama N, Murakami K, Livingstone MBE, *et al.* Development of a food-based diet quality score for Japanese: associations of the score with nutrient intakes in young, middle-aged and older Japanese women. *J Nutr Sci.* 2016;5:e41.
39. GBD 2017 Diet Collaborators. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet.* 2019;393:1958–1972.
40. Kubota K, Itoh H, Tasaka M, *et al.* Changes of maternal dietary intake, bodyweight and fetal growth throughout pregnancy in pregnant Japanese women. *J Obstet Gynaecol Res.* 2013;39:1383–1390.
41. Ishitsuka K, Sasaki S, Yamamoto-Hanada K, *et al.* Changes in dietary intake in pregnant women from periconception to pregnancy in the Japan environment and children's study: a nationwide Japanese birth cohort study. *Matern Child Health J.* 2020;24:389–400.
42. Okubo H, Nakayama SF. Periconceptional diet quality and its relation to blood heavy metal concentrations among pregnant women: the Japan environment and children's study. *Environ Res.* 2023;225:115649.

43. Okubo H, Nakayama SF. Periconceptional maternal diet quality influences blood heavy metal concentrations and their effect on low birth weight: the Japan environment and children's study. *Environ Int.* 2023;173:107808.
44. Koyama T. A food consumption-based diet quality score and its correlation with nutrient intake adequacy among Japanese children. *Cureus.* 2021;13:e19337.
45. Cole TJ, Bellizzi MC, Flegal KM, *et al.* Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ.* 2000;320:1240–1243.
46. Hure A, Young A, Smith R, *et al.* Diet and pregnancy status in Australian women. *Public Health Nutr.* 2009;12:853–861.
47. Kurotani K, Nakade M, Takimoto H. Consumption of meals consisting of grain, fish and meat, and vegetable dishes and the relation with nutritional or health status among the Japanese population: a systematic review (in Japanese). *Jpn J Nutr Diet.* 2018;76:77–88.
48. Nishimura T, Murakami K, Livingstone MB, *et al.* Adherence to the food-based Japanese dietary guidelines in relation to metabolic risk factors in young Japanese women. *Br J Nutr.* 2015;114: 645–653.
49. Ministry of Health, Labour and Welfare, Japan. *Dietary Reference Intakes for Japanese*. Chiyoda, Tokyo: Ministry of Health, Labour and Welfare, Japan; 2019.
50. Ministry of Health Labour and Welfare, Japan. *Specified Report of Vital Statistics.* Chiyoda, Tokyo: Ministry of Health, Labour and Welfare, Japan; 2021.
51. Ministry of Health, Labour and Welfare, Japan. *The National Health and Nutrition Survey in Japan, 2018*. Chiyoda, Tokyo: Ministry of Health, Labour and Welfare, Japan; 2019.