Original Article

Living environments long-term after the Great East Japan Earthquake and nutritional intake among recent mothers

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Background and Objectives: Although large-scale natural disasters and the resultant changes in living environments worsen dietary habits among adults immediately after the disasters, whether this association remains for a long period is unclear. This is particularly important for recent mothers because lactating women require additional nutrition for milk production. Thus, we investigated the association of living environments with dietary habits and nutritional intake of recent mothers between four and seven years after the Great East Japan Earthquake (11th March, 2011). **Methods and Study Design:** We analyzed 8,551 mothers who participated to the Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study. Living environments were characterized into four categories: "same home before the earthquake", "rental housing", "reconstructed home", and "acquaintance's home". Dietary habits and nutritional intake were evaluated using a food frequency questionnaire answered 12 months after their deliveries (the questionnaire was answered between March 2015 and July 2018). **Results:** Multiple linear regression analyses demonstrated that mothers in 'rental housing' or 'reconstructed home' had a significantly lower intake of almost all nutrients or certain nutrients, respectively, compared with those residing in 'same home before the earthquake'. However, fewer significant differences were detected between the nutritional intake of the mothers lodging in an 'acquaintance's home' and that of those living in 'same home before the earthquake'. **Conclusions:** Our findings indicate that living environments long-term after large-scale disasters are associated with dietary habits and nutritional intake among recent mothers.

Key Words: natural disasters, housing, diet, food and nutrition, postpartum period

INTRODUCTION

Large-scale natural disasters and their consequence on living environments are one of the major factors responsible for deterioration of dietary habits and nutritional intake.[1-3] Soon after the Great East Japan Earthquake, on 11 March, 2011, meals at evacuation shelters were found to be biased toward carbohydrates, lacked proteins (meat, fish, egg, beans, etc.) and vegetables, since there was a shortage of food stocks, cookware, and gas, and food was difficult to procure.[4,5] About half a year after the earthquake, some evacuees moved to temporary housing and prepared their own meals,[6] while others moved to their relatives' homes or returned to their own homes. A year after the earthquake, it was found that people in temporary housing or rental housing had a lower intake of fruits, vegetables, meat, soy products, and dairy products

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compared with those in their relatives' homes or their own homes.[7] This helped identify nutritional risk groups that emerged after large-scale disasters and needed appropriate nutritional support. However, the association of post-disaster living environments with dietary habits and nutritional intake among adults has only been investigated for up to a year after the disaster, and the association after a longer period remains unknown.

The dietary habits and nutritional intake of recent mothers are important because they require more nutrients to produce breast milk and the lack of certain nutrients can affect their health as well as their infant's health.[8-10] To our knowledge, despite the importance of dietary habits and nutritional intake in recent mothers, the association between post-disaster living environments and dietary habits has not been investigated in this nutritionally vulnerable group. Thus, this study aimed to investigate the association of living environments between four and seven years after the Great East Japan Earthquake with dietary habits among recent mothers who had experienced it.

METHODS

Study design and participants

This study was based on the data from the Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study (TMM BirThree Cohort Study), which is a population-based prospective cohort study conducted by the Tohoku University Tohoku Medical Megabank Organization (ToMMo). The details of the TMM BirThree Cohort Study have been described previously.[11,12] Briefly, 22,493 pregnant women in their first trimester were recruited between July 2013 and March 2017 in approximately 50 obstetric clinics and hospitals in both rural and urban areas of Miyagi prefecture, Japan. The TMM BirThree Cohort Study was approved by the Ethics Committee of ToMMo (2013-1-103-1) and conducted in accordance with the Declaration of Helsinki and all other appropriate guidelines. Written informed consent was obtained from all participants. A dataset, fixed on January 31st, 2019, was used for our analysis. The flowchart describing the selection of participants is shown in Figure 1.

Living environments

Data on the mothers' living environments were obtained from a questionnaire that they had answered 12 months after their deliveries (Supplementary table 1). The questionnaire was answered between March 2015 and July 2018, which was between four and seven years after the earthquake. Living environments were quantified using the question 'Which of these is your living environments now?'. Participants selected one of the seven options: 'the home where I have lived before the earthquake' (same home before the earthquake), 'rental housing in a new place provided by the local government', 'moved to rental housing in a new place not provided by the local government', 'the home reconstructed where I have lived before the earthquake', 'the home reconstructed in a new place', 'family's, relative's, or friend's home' (acquaintance's home), or 'temporary housing'. For our analysis, 'rental housing in a new place provided by the local government' and 'moved to rental housing in a new place not provided by the local government' were combined into 'rental housing'. Also, 'the home reconstructed where I have lived before the earthquake' and 'the home reconstructed in a new place' were combined into 'reconstructed home'. Participants who selected 'temporary housing' were excluded from the analysis because there were only 42 respondents (0.3%).

Dietary intake

Information on dietary intake was obtained from a food frequency questionnaire (FFQ). The FFQ is a self-administered questionnaire developed to investigate dietary habits and nutritional intake by questioning average dietary intake over the past few months. In this study, mothers answered an FFQ, 12 months after their deliveries, about average dietary intake over the past 12 months. For supplemental analysis, another FFQ which was answered during the second trimester of pregnancy, investigating average dietary intake from the first trimester to the second trimester of pregnancy, was used. These FFQs were used to estimate the mothers' usual intake frequency and portion sizes of 130 food items and is based on the FFQ from the Japan Public Health Centre-based prospective (JPHC) study.[13] The response option 'constitutionally unable to eat it' for individual food items is unique to the FFQ of our study.

Regarding frequency, the possible responses consisted of 'constitutionally unable to eat it', 'never or less than once a month', 'from one to three times a month', 'once or twice a week', 'three or four times a week', 'five or six times a week', 'once a day', 'two or three times a day', 'from four to six times a day', and 'seven or more times a day'. The reference amounts of each food item per serving were presented by pictures or texts, and the portion sizes were specified as a multiplier to the reference ('less than half', 'one', and 'more than one and a half times'). The daily intake of each food item was calculated by multiplying the frequency and the portion sizes. Food items were converted into food categories and the daily intake of each nutrient was calculated based on the Standard Tables of Food Composition in Japan (Fifth Revised and Enlarged Edition 2005).[14] For our analysis, we selected 13 food categories (vegetables were subcategorized into 'green and yellow vegetables' and 'non-green and non-yellow vegetables') and 28 nutrients which had Spearman's correlation coefficients of 0.3 or higher between estimated intakes measured by the FFQ and the dietary record method.[15-18]

Potential cofounders

Variables considered to be associated with living environments and dietary habits based on previous studies were selected as confounders.[7] Data on the mother's annual household income were obtained from a questionnaire answered during second trimester of pregnancy (Supplementary table 1). Other variables (mother's age, height, weight, educational qualification, cigarette smoking, and alcohol consumption) were obtained from a questionnaire answered 12 months after delivery. The mother's age was considered to be a continuous variable. Body mass index (BMI) was calculated by dividing weight (kg) by the square of height (m^2) and was also

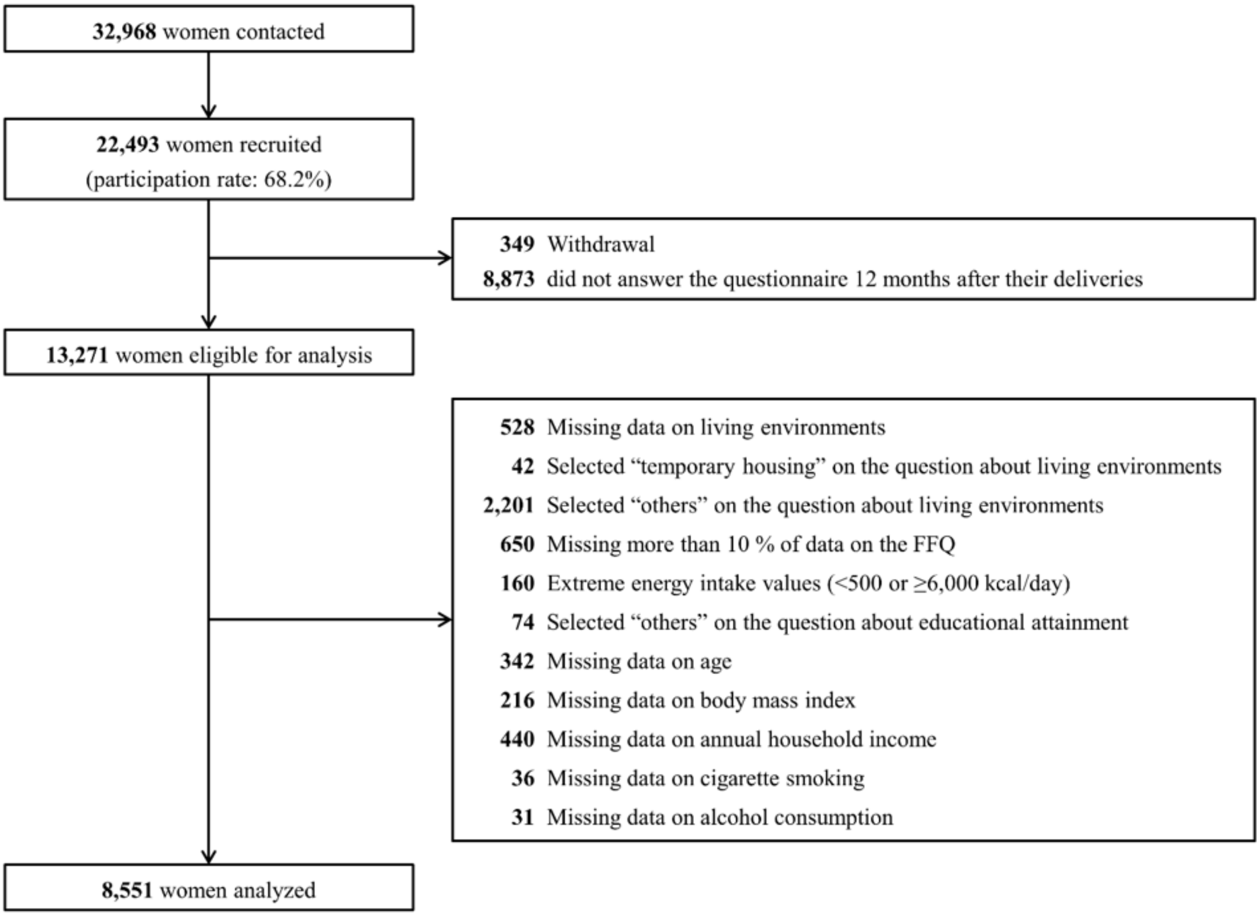

Figure 1. Flowchart describing the selection of participants.

considered to be a continuous variable. Educational qualification was divided into three categories: high school graduate or less (elementary, junior high school, or senior high school), college graduate (2-year college or special training school), and university graduate or above (university or graduate school). Mothers who selected the 'others' option were excluded due to the ambiguity of its interpretation. The answers for annual household income were categorized into '<4,000,000', '4,000,000-5,999,999', and '≥6,000,000' Japanese yen per year. The options for both cigarette smoking and alcohol consumption were 'never', 'former', and 'current'. The study date of the questionnaire answered 12 months after delivery was categorized by year (2015, 2016, 2017, and 2018).

Statistical analysis

Regarding descriptive epidemiological information such as maternal background attributes and intake of food categories and nutrients (Table 1, 2, and Supplementary table 2), continuous variables were expressed as medians and interquartile ranges (IQRs), and categorical variables were expressed as frequencies and percentages. Associations of living environments with the intake of food categories and nutrients were evaluated by multiple linear regression models, adjusted for potential confounders mentioned above and for energy intake using the residual method (Table 3, Supplementary table 3),[19] and the regression coefficients and 95% confidence intervals (95% CI) were calculated. Mothers in 'same home before the earthquake' were set as the reference category. For supplemental analysis, associations of living environments with the intake of food categories and nutrients during pregnancy were evaluated by multiple linear regression models adjusted for potential confounders mentioned above and adjusted for energy intake by the residual method (Supplementary table 4 and 5). R (version 4.0.1) was used for all analyses, and a p-value <0.05 was considered statistically significant.

RESULTS

Characteristics of participants

In total, 8,551 mothers were analysed. The characteristics of mothers from each living environment are shown in Table 1. Mothers living in 'same home before the earthquake' was the biggest group (n=3,515: 41.1%), followed by those living in 'rental housing' (n=2,368: 27.7%), followed by those in a 'reconstructed home' (n=2,285: 26.7%), and finally, those in an 'acquaintance's home' (n=383: 4.5%).

Mothers of the 'same home before the earthquake' group had the highest percentage of respondents who currently smoked. Mothers of the 'rental housing' group had the lowest BMI and the highest percentage of respondents who were university graduates or above. Mothers of the 'reconstructed home' group had the highest percentage of respondents with an annual household income of ≥6,000,000 Japanese yen per year, and the lowest percentage of respondents who currently smoked. Mothers of the 'acquaintance's home' group, on average, were the youngest and had the highest BMI. They had the

Table 1. Characteristics of the participants from each living environment

Variables	Total (n=8,551)		Living environments: Same home before the earthquake (n=3,515)		Rental housing (n=2,368)		Reconstructed home (n=2,285)		Acquaintance's home (n=383)	
	Median or n	IQR or %	Median or n	IQR or %	Median or n	IQR or %	Median or n	IQR or %	Median or n	IQR or %
Age (years)	33.0	30.0–37.0	34.0	30.5–38.0	32.0	29.0–36.0	34.0	31.0–37.0	32.0	28.0–36.0
Body mass index (kg/m^2) †	20.8	19.2–22.9	20.8	19.3–23.2	20.6	19.1–22.6	20.8	19.2–22.8	21.2	19.5–23.3
Educational qualification, n and %										
High school graduate or less	2,732	31.9	1,218	34.7	690	29.1	679	29.7	145	37.9
College graduate	3,270	38.2	1,375	39.1	868	36.7	908	39.7	119	31.1
University graduate or above	2,549	29.8	922	26.2	810	34.2	698	30.5	119	31.1
Annual household income (Japanese yen/year), n and %										
<4,000,000	2,879	33.7	1,251	35.6	888	37.5	550	24.1	190	49.6
4,000,000-5,999,999	2,851	33.3	1,102	31.4	857	36.2	791	34.6	101	26.4
≥6,000,000	2,821	33.0	1,162	33.1	623	26.3	944	41.3	92	24.0
Cigarette smoking, n and %										
Never	5,905	69.1	2,343	66.7	1,677	70.8	1,617	70.8	268	70.0
Former	2,229	26.1	980	27.9	569	24.0	584	25.6	96	25.1
Current	417	4.9	192	5.5	122	5.2	84	3.7	19	5.0
Alcohol consumption, n and %										
Never	4,913	57.5	2,068	58.8	1,297	54.8	1,324	57.9	224	58.5
Former	1,727	20.2	641	18.2	561	23.7	440	19.3	85	22.2
Current	1,911	22.3	806	22.9	510	21.5	521	22.8	74	19.3
Study year of questionnaires at 12 months after delivery, n and %										
2015	1,679	19.6	794	22.6	440	18.6	375	16.4	70	18.3
2016	2,358	27.6	1,041	29.6	607	25.6	590	25.8	120	31.3
2017	3,549	41.5	1,321	37.6	1,039	43.9	1,025	44.9	164	42.8
2018	965	11.3	359	10.2	282	11.9	295	12.9	29	7.6

IQR: Interquartile range.

†Body mass index was calculated by dividing weight (kg) by the square of height (m^2).

Table 2. Intake of food categories and nutrients (not energy adjusted) for each living environment 12 months after the deliveries

Variables	Total (n=8,551)		Living environments: Same home before the earthquake (n=3,515)		Rental housing (n=2,368)		Reconstructed home (n=2,285)		Acquaintance's home (n=383)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Food categories (g)										
Cereals	448	357–530	456	370–535	436	349–521	441	353–525	454	341–532
Pulses	49.3	27.5–86.1	50.2	28.6–87.5	46.4	25.0–81.1	49.9	28.4–88.1	50.9	26.2–92.1
Nuts and seeds	0	0–1.33	0	0–1.33	0	0–0.67	0	0–1.33	0	0–1.33
Vegetables	147	97.9–217	151	101–226	139	93.7–204	147	98.9–215	148	92.6–222
Green & yellow	55.2	34.2–88.4	57.2	34.6–92.1	51.1	32.6–82.9	56.3	35.8–88.2	56.7	33.4–91.0
non-Green & non-yellow	86.9	57.9–127	90.3	60.1–132	83.3	55.3–119	86.8	58.2–127	86.3	54.8–132
Fruits	95.4	39.3–172	103	42.8–185	86.5	34.7–155	95.8	40.8–168	91.2	37.6–178
Mushroom	9.90	4.29–15.6	9.90	4.29–15.7	9.90	4.00–15.0	9.90	5.33–15.6	9.90	4.00–15.0
Fish and shellfish	41.9	24.7–64.0	44.1	26.7–65.8	37.3	21.7–59.4	42.8	26.0–66.3	41.7	22.6–64.2
Meat	74.4	49.9–109	75.7	49.4–110	72.2	49.4–107	75.1	51.1–110	73.6	46.9–111
Eggs	25.0	10.7–39.3	25.0	10.7–39.3	25.0	10.7–39.3	25.0	10.7–39.3	25.0	10.7–39.3
Milk and dairy products	154	72.9–270	160	72.9–271	142	66.8–259	161	78.1–281	147	56.6–257
Confectioneries	17.4	8.00–31.5	17.4	8.00–31.7	16.5	8.00–30.4	17.4	8.67–32.0	18.8	8.04–33.7
Alcoholic beverages	0	0–0	0	0–0	0	0–0	0	0–0	0	0–0
Non-alcoholic beverages	292	136–474	309	157–502	236	114–423	295	136–477	293	140–510
Energy (kcal)	1,710	1,400–2,130	1,750	1,430–2,190	1,660	1,360–2,050	1,710	1,400–2,120	1,690	1,360–2,180
Nutrients										
Protein (g)	61.1	48.0–79.1	62.9	49.0–81.2	58.3	46.2–75.4	61.5	48.5–79.0	61.5	46.8–82.1
Fat (g)	61.1	45.6–81.7	62.6	46.2–83.8	58.8	43.9–77.9	61.7	46.9–81.5	60.8	44.1–84
Carbohydrate (g)	217	178–263	223	184–268	210	173–256	215	179–260	214	169–270
Sodium (mg)	3,210	2,420–4,250	3,360	2,530–4,420	2,990	2,270–3,980	3,230	2,430–4,220	3,390	2,410–4,370
Potassium (mg)	2,140	1,630–2,860	2,220	1,700–2,960	2,010	1,540–2,680	2,150	1,670–2,870	2,150	1,530–2,950
Calcium (mg)	473	327–666	486	334–683	447	308–626	484	337–678	464	314–652
Magnesium (mg)	223	174–288	230	179–298	210	166–269	225	175–291	223	162–295
Phosphorus (mg)	957	743–1,240	988	760–1,270	903	712–1,180	968	756–1,250	936	740–1,250
Iron (mg)	6.78	5.27–8.79	6.96	5.43–9.07	6.41	5.05–8.38	6.79	5.26–8.81	7.06	5.31–9.11
Zinc (mg)	7.42	5.93–9.39	7.63	6.02–9.63	7.12	5.78–9.02	7.45	6.00–9.39	7.47	5.86–9.71
Copper (mg)	1.02	0.82–1.28	1.05	0.84–1.33	0.98	0.78–1.22	1.02	0.81–1.28	1.03	0.80–1.34
Manganese (mg)	2.34	1.86–2.95	2.43	1.94–3.07	2.22	1.78–2.76	2.32	1.84–2.94	2.38	1.82–3.06
Retinol equivalents (μg RE)	502	330–784	523	346–813	474	312–761	495	335–764	503	311–760
Vitamin D (μg)	5.69	3.79–8.87	5.93	4.03–9.26	5.32	3.45–8.05	5.78	3.88–8.92	5.50	3.68–9.05
Vitamin K (μg)	220	144–331	227	148–336	210	137–314	222	146–333	211	141–334
Vitamin B_1 (mg)	0.84	0.65–1.09	0.86	0.66–1.13	0.80	0.62–1.05	0.84	0.65–1.09	0.83	0.62–1.10
Vitamin B-2 (mg)	1.10	0.81–1.49	1.13	0.83–1.53	1.03	0.77–1.41	1.12	0.83–1.49	1.07	0.8–1.55
Vitamin B-6 (mg)	1.11	0.87–1.45	1.15	0.90–1.49	1.06	0.83–1.37	1.12	0.87–1.46	1.12	0.84–1.49
Vitamin B-12 (μg)	4.73	3.14–6.93	4.95	3.34–7.23	4.38	2.85–6.45	4.76	3.21–7.03	4.68	2.94–6.98
Folate (μg)	256	191–351	264	199–365	241	180–327	257	192–352	268	183–363
Pantothenic acid (mg)	5.96	4.62–7.77	6.12	4.72–8.00	5.67	4.46–7.43	6.00	4.67–7.77	5.91	4.56–7.96

IQR: Interquartile range; RE: Retinol equivalents.

Table 2. Intake of food categories and nutrients (not energy adjusted) for each living environment 12 months after the deliveries (cont.)

Variables	Total (n=8,551)		Living environments							
			Same home before the earthquake (n=3,515)		Rental housing (n=2,368)		Reconstructed home (n=2,285)		Acquaintance's home (n=383)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Vitamin C (mg)	72.2	48.4–105	76.0	50.9–112	65.4	45.2–95.6	73.7	50.3–103	72.9	44.7–108
Cholesterol (mg)	258	183–346	262	186–352	246	175–331	261	187–345	271	172–355
Dietary fibre (g)	10.4	7.80–14.0	10.8	8.07–14.4	9.84	7.48–13.0	10.7	7.85–14.2	10.6	7.38–14.5
α-carotene (μg)	527	248–819	528	249–824	524	244–815	530	253–819	523	235–818
β-carotene (μg)	2,550	1,590–3,800	2,600	1,630–3,930	2,410	1,510–3,610	2,600	1,670–3,770	2,460	1,460–4,010
Lycopene (μg)	619	301–1,190	638	328–1,300	533	267–1,020	624	328–1,200	684	280–1,230
β-Cryptoxanthin (μg)	330	99.7–668	343	106–698	311	91.9–636	325	101–662	326	80.3–659

IQR: Interquartile range; RE: Retinol equivalents

Table 3. Association of living environments with energy adjusted intake of food categories and nutrients after 12 months from the deliveries†

Variables	Same home before the earthquake (n=3,515)	Rental housing (n=2,368)		Reconstructed home (n=2,285)		Acquaintance's home (n=383)	
		β‡	95% CI	β	95% CI	β	95% CI
Food categories (g)							
Cereals	Reference	-2.7	-9.6, 4.2	-7.3‡	-14.2, -0.4	-6.6	-20.5, 7.2
Pulses	Reference	-1.0	-5.4, 3.4	-1.2	-5.6, 3.2	7.7	-1.1, 16.4
Nuts and seeds	Reference	0.01	-0.19, 0.21	0.16	-0.04, 0.36	0.08	-0.32, 0.49
Vegetables	Reference	-14.2‡	-20.9, -7.6	-7.9‡	-14.6, -1.2	-7.7	-21.1, 5.6
Green & yellow	Reference	-5.8‡	-9.5, -2.0	-1.9	-5.7, 1.8	-2.4	-9.9, 5.2
non-Green & non-yellow	Reference	-8.5‡	-12.6, -4.4	-6.0‡	-10.1, -1.9	-5.3	-13.5, 2.8
Fruits	Reference	-12.9‡	-20.7, -5.2	-12.4‡	-20.2, -4.6	-12.9	-28.4, 2.6
Mushroom	Reference	0.05	-0.55, 0.64	0.21	-0.39, 0.81	-1.17	-2.35, 0.02
Fish and shellfish	Reference	-2.9‡	-4.9, -0.9	-0.3	-2.3, 1.7	2.7	-1.3, 6.7
Meat	Reference	0.3	-2.4, 2.9	1.4	-1.2, 4.1	2.0	-3.3, 7.3
Eggs	Reference	0.17	-1.64, 1.99	0.38	-1.43, 2.20	1.87	-1.75, 5.49
Milk and dairy products	Reference	9.6	-5.9, 25.1	4.8	-10.8, 20.3	0.1	-30.8, 31.1
Confectioneries	Reference	1.45‡	0.07, 2.83	1.14	-0.24, 2.52	1.76	-0.99, 4.51
Alcoholic beverages	Reference	2.0	-4.8, 8.8	9.2‡	2.4, 16.0	-8.5	-22.0, 5.1
Non-alcoholic beverages	Reference	-28.3‡	-48.3, -8.2	-10.2	-30.2, 9.8	6.0	-34.0, 45.9
Nutrients							
Protein (g)	Reference	-0.5	-1.1, 0.1	0.2	-0.4, 0.8	1.7‡	0.5, 2.9
Fat (g)	Reference	0.4	-0.3, 1.2	0.8‡	0.0, 1.6	1.2	-0.4, 2.7

RE: retinol equivalents

†Multiple linear regression model was adjusted for the mother's age (continuous), body mass index (continuous), educational qualification (high school graduate or less; college graduate; university graduate or above), annual household income (<4,000,000; 4,000,000-5,999,999; ≥6,000,000 Japanese yen/year), cigarette smoking (never; former; current), alcohol consumption (never; former; current), study year of the questionnaire answered after 12 months from delivery (2015; 2016; 2017; 2018). Intake of food categories and nutrients was adjusted by energy intake using the residual method.

‡Statistically significant associations.

Table 3. Association of living environments with energy adjusted intake of food categories and nutrients after 12 months from the deliveries[†]

Variables	Same home before the earthquake (n=3,515)	Rental housing (n=2,368)		Reconstructed home (n=2,285)		Acquaintance's home (n=383)	
		β ‡	95% CI	β	95% CI	β	95% CI
Carbohydrate (g)	Reference	-1.1	-3.2, 1.0	-3.0‡	-5.1, -0.8	-3.6	-7.8, 0.6
Sodium (mg)	Reference	-174‡	-228, -121	-69.2‡	-123, -15.4	75.2	-32.1, 183
Potassium (mg)	Reference	-72.0‡	-105, -39.6	-32.8‡	-65.3, -0.3	-3.4	-68.3, 61.4
Calcium (mg)	Reference	3.7	-13.8, 21.3	5.2	-12.4, 22.8	7.2	-27.8, 42.3
Magnesium (mg)	Reference	-6.1‡	-8.9, -3.3	-2.1	-4.8, 0.7	2.6	-2.9, 8.1
Phosphorus (mg)	Reference	-3.8	-16.7, 9.1	4.6	-8.3, 17.5	13.4	-12.3, 39.1
Iron (mg)	Reference	-0.203‡	-0.305, -0.100	-0.095	-0.197, 0.008	0.182	-0.023, 0.386
Zinc (mg)	Reference	-0.057	-0.120, 0.006	-0.029	-0.092, 0.034	0.155‡	0.029, 0.281
Copper (mg)	Reference	-0.021‡	-0.034, -0.007	-0.014‡	-0.027, -0.001	0.018	-0.009, 0.044
Manganese (mg)	Reference	-0.119‡	-0.166, -0.072	-0.096‡	-0.143, -0.049	-0.013	-0.107, 0.081
Retinol equivalents (μg RE)	Reference	-0.6	-22.9, 21.8	-19.1	-41.4, 3.3	14.8	-29.8, 59.4
Vitamin D (μg)	Reference	-0.24‡	-0.47, -0.01	-0.01	-0.24, 0.22	0.38	-0.08, 0.84
Vitamin K (μg)	Reference	-5.7	-15.3, 3.9	-3.0	-12.6, 6.7	10.1	-9.1, 29.3
Vitamin B-1 (mg)	Reference	-0.010‡	-0.020, -0.001	-0.004	-0.013, 0.006	-0.008	-0.027, 0.011
Vitamin B-2 (mg)	Reference	-0.001	-0.025, 0.024	0.004	-0.021, 0.028	0.035	-0.014, 0.085
Vitamin B-6 (mg)	Reference	-0.031‡	-0.045, -0.016	-0.014	-0.028, 0.001	0.011	-0.018, 0.040
Vitamin B-12 (μg)	Reference	-0.186‡	-0.349, -0.022	-0.012	-0.176, 0.152	0.255	-0.072, 0.582
Folate (μg)	Reference	-13.2‡	-18.7, -7.6	-9.8‡	-15.4, -4.2	-1.4	-12.5, 9.8
Pantothenic acid (mg)	Reference	0	-0.084, 0.084	-0.006	-0.090, 0.078	0.114	-0.054, 0.281
Vitamin C (mg)	Reference	-7.6‡	-10.2, -5.0	-5.5‡	-8.0, -2.9	-4.9	-10.0, 0.3
Cholesterol (mg)	Reference	0.7	-7.4, 8.9	2.1	-6.0, 10.2	13.1	-3.2, 29.3
Dietary fibre (g)	Reference	-0.47‡	-0.70, -0.24	-0.29‡	-0.52, -0.06	-0.04	-0.50, 0.41
α-carotene (μg)	Reference	-9.0	-43.4, 25.5	-5.1	-39.6, 29.4	-40.5	-109.3, 28.4
β-carotene (μg)	Reference	-137‡	-264, -8.7	-97.3	-225, 30.7	-215	-470, 40.6
Lycopene (μg)	Reference	-230	-501, 40.5	19.6	-251, 291	92.2	-448, 633
β-Cryptoxanthin (μg)	Reference	-56.1‡	-101, -10.8	-65.3‡	-111, -20.0	-88.7	-179, 1.6

RE: retinol equivalents

[†]Multiple linear regression model was adjusted for the mother's age (continuous), body mass index (continuous), educational qualification (high school graduate or less; college graduate; university graduate or above), annual household income (< 4,000,000; 4,000,000-5,999,999; ≥ 6,000,000 Japanese yen/year), cigarette smoking (never; former; current), alcohol consumption (never; former; current), study year of the questionnaire answered after 12 months from delivery (2015; 2016; 2017; 2018). Intake of food categories and nutrients was adjusted by energy intake using the residual method.

[‡]Statistically significant associations

highest percentage of respondents who were high-school graduates or less, and those who had an annual household income of <4,000,000 Japanese yen per year. Further, they had the lowest percentage of respondents who currently consumed alcohol.

Intake of food categories and nutrients for each living environment 12 months after the deliveries are shown in Table 2 and Supplementary Table 2. The median energy intake of all participants was 1,710 (IQR: 1,400–2,130) kcal/day. The median energy intake was the highest in the mothers of the 'same home before the earthquake' group (1,750 (IQR: 1,430–2,190) kcal/day) and the lowest in the mothers of the 'rental housing' group (1,660 (IQR: 1,360–2,050) kcal/day).

Association of living environments with the intake of food categories and nutrients 12 months after the deliveries

The association of living environments with the intake of food categories and nutrients 12 months after the deliveries are shown in Table 3 (energy-adjusted models) and Supplementary Table 3 (not energy-adjusted models). Mothers from the 'rental housing' group and the 'reconstructed home' group had significantly lower energy intake compared to mothers from the 'same home before the earthquake' group (Supplementary table 3).

Mothers from the 'rental housing' group, in models that had not been adjusted for energy (Supplementary Table 3), had a significantly lower intake of cereals, pulses, vegetables, green and yellow vegetables, non-green and non-yellow vegetables, fruits, fish and shellfish, meat, non-alcoholic beverages, and all nutrients compared with mothers from the 'same home before the earthquake' group. Many of these associations (vegetables, green and yellow vegetables, non-green and non-yellow vegetables, fruits, fish and shellfish, non-alcoholic beverages, sodium, potassium, magnesium, iron, copper, manganese, vitamin D, vitamin B-1, vitamin B-6, vitamin B-12, folate, vitamin C, dietary fibre, β-carotene, β-cryptoxanthin) remained statistically significant after adjusting for energy intake (Table 3). These mothers also had a significantly higher intake of confectioneries compared with mothers from the 'same home before the earthquake' group, in the energy-adjusted model.

Mothers from the 'reconstructed home' group, in models that had not been adjusted for energy, had a significantly higher intake of alcoholic beverages, and a lower intake of cereals, vegetables, non-green and non-yellow vegetables, fruits, carbohydrate, sodium, potassium, magnesium, iron, zinc, copper, manganese, retinol, vitamin B-1, vitamin B-6, folate, vitamin C, dietary fibre, β-carotene, and β-cryptoxanthin compared to mothers from the 'same home before the earthquake' group. Many of these associations (cereals, vegetables, non-green and non-yellow, fruits, alcoholic beverages, carbohydrates, sodium, potassium, copper, manganese, folate, vitamin C, dietary fibre, and β-cryptoxanthin) remained statistically significant after adjusting for energy intake. These mothers also had significantly higher fat intake compared with mothers from the 'same home before the earthquake' group in the energy-adjusted model.

Mothers from the 'acquaintance's home' group, in models that had not been adjusted for energy, had a significantly lower intake of mushroom and β-cryptoxanthin compared with mothers from the 'same home before the earthquake' group. These mothers also had a significantly higher intake of protein and zinc compared with mothers from the 'same home before the earthquake' group in the energy-adjusted model.

Association of living environments with the intake of food categories and nutrients during pregnancy

The associations of living environments with the intake of food categories and nutrients during pregnancy are shown in Supplementary Table 4 and 5. Mothers from the 'rental housing' group had significantly lower energy intake compared with mothers from the 'same home before the earthquake' group (Supplementary table 4).

In energy-adjusted models (Supplementary table 5), mothers from the 'rental housing' group had a higher intake of alcoholic beverages and had a lower intake of cereals, vegetables, green and yellow vegetables, non-green and non-yellow vegetables, fruits, fish and shellfish, non-alcoholic beverages, carbohydrate, sodium, potassium, magnesium, iron, copper, manganese, vitamin D, vitamin K, vitamin B-1, vitamin B-6, vitamin B-12, folate, vitamin C, dietary fibre, β-carotene, lycopene, and β-cryptoxanthin compared with mothers from the 'same home before the earthquake' group.

Mothers from the 'reconstructed home' group had a higher intake of meat, fat, and cholesterol and had a lower intake of vegetables, green and yellow vegetables, non-green and non-yellow vegetables, fruits, carbohydrates, sodium, potassium, magnesium, copper, manganese, folate, vitamin C, dietary fibre, and β-cryptoxanthin compared with mothers from the 'same home before the earthquake' group.

Mothers from the 'acquaintance's home' group had a higher intake of confectioneries compared with mothers from the 'same home before the earthquake' group.

DISCUSSION

We found that living environments, between four and seven years after the Great East Japan Earthquake, were associated with the dietary habits and nutritional intake of recent mothers. Mothers of the 'rental housing' group had a lower energy intake and a lower intake of nutrients and food from most categories compared to mothers of the 'same home before the earthquake' group. Mothers of the 'reconstructed home' group also had a lower energy intake and a lower intake of some food categories and nutrients compared to mothers of the 'same home before the earthquake' group. Mothers of the 'acquaintance's home' group did not show a difference in energy intake and had a higher intake of protein and zinc compared with mothers of the 'same home before the earthquake' group.

The median daily intake of vegetables and fruits was found to be only 147 g and 95 g respectively in this study, whereas the recommended daily intake should be 350 g and 200 g, respectively.[20,21] Thus, the low intake of vegetables and fruits is a serious problem in participants in this study. In the multiple linear regression model (not energy-adjusted), mothers from the 'rental housing' group and the 'reconstructed home' group had a significantly lower energy intake and a lower intake of many of food categories and nutrients compared with mothers from the 'same home before the earthquake', indicating that they comprehensively eat a smaller amount of food in daily life compared with mothers from the 'same home before the earthquake' group.

We used energy-adjusted models to evaluate the intake of food categories and nutrients relative to energy intake. In energy-adjusted models, mothers of the 'rental housing' group had a significantly lower intake of vegetables, green and yellow vegetables, non-green and non-yellow vegetables, fruits, fish and shellfish, non-alcoholic beverages, and many nutrients and a higher intake of confectionaries compared to mothers of the 'same home before the earthquake' group. This results support a previous survey on the adult population in the Fukushima prefecture, conducted a year after the Great East Japan Earthquake, which showed those in 'evacuation shelters or temporary housings' and 'rental housings or apartments' had a lower intake of vegetables and fruits compared with those in 'same home before the earthquake or relatives' home'.[7] Our results indicate a long-lasting relationship between the living environment, after the earthquake, and dietary habits in recent mothers. From the supplemental analysis, using FFQs during pregnancy, we found that the relationships between the living environment and intake of food categories and nutrients during pregnancy were similar to those 12 months after their deliveries (Table 3, Supplementary Table 5). These results indicate that mothers from the 'rental housing' group had a poorer nutritional intake during pregnancy compared with mothers from the 'same home before the earthquake' group.

Mothers from the 'reconstructed home' group also had a significantly lower intake of cereals, vegetables, non-green and non-yellow vegetables, fruits, carbohydrate, sodium, potassium, copper, manganese, folate, vitamin C, dietary fibre, and β-cryptoxanthin compared with mothers from the 'same home before the earthquake' group, in energy-adjusted models. However, the effect size tended to be smaller than mothers from the 'rental housing' group. This might be because mothers from the 'reconstructed home' group had enough money to rebuild their homes, and this is known to be positively associated with the intake of nutritious foods.[22] They had the highest percentage of respondents with the highest income in this study (Table 1).

To clarify the impact of living in a new place on nutrient intake, we excluded mothers in the 'home reconstructed where I have lived before the earthquake' group (n=187) from the 'home reconstructed' group and reanalysed the association between living environments with the intake of food categories and nutrients 12 months after the deliveries. As a result, compared with results obtained before exclusion, mean estimates of intake of most of food categories and nutrients in 'the home reconstructed' became smaller (data not shown). This result indicates that living in a new area might deteriorate their dietary habits.

Mothers from the 'acquaintance's home' group showed few associations between living environments and intake of food categories and nutrients. This might be because the number of participants in this group was much smaller than that in the other groups, decreasing statistical power.

Some of the limitations of this study include the fact that participants in this analysis were limited to those who answered questionnaires after 12 months from their deliveries, and a large number of mothers were excluded from the analysis, resulting in a possible selection bias. Differences in the characteristics of the 13,942 mothers who were excluded and the 8,551 mothers who were included are shown in Supplementary Table 6. Mothers who were excluded from analysis were more likely to be younger, less educated, had a lower annual household income, had a higher chance of smoking and drinking, and had a lower intake of most food categories and nutrients compared with mothers who were analysed. Education and household income are known to be positively associated with the intake of nutritious foods.[23] On the other hand, smoking and drinking habits are known to be negatively associated with the intake of nutritious foods.[24,25] Thus, the nutritional intake of the participants in this analysis might have been overestimated. Second, we did not inquire into the reasons for moving after the earthquake, so we do not know if all post-disaster moves were direct results of the earthquake. Third, although environment related to food supply can affect the nutritional intake of subjects,[2,3] we did not ask about environment related to food supply and we could not take it into account for our analysis. Fourth, since the dietary data was obtained from self-administrated FFQs, measurement errors in dietary consumption were inevitable. Fifth, the FFQs used in this study was a modified version of an FFQ used in the JPHC study, which has been validated in the Japanese population.[16,26,27] We added a response option of 'constitutionally unable to eat it' in the question about the frequency of dietary intake. However, this was treated to be equivalent to 'never or less than once a month', to calculate the amount of intake of each food item. Thus, it would have little impact on the interpretation of the results.

Our study has several strengths. First, studies that have focused on the relationship between living environments and dietary habits after a disaster are very limited.[5,7] Existing studies focus on the time window just after the disaster, whereas this study focused on a period of between four and seven years after the earthquake, and indicated a long-lasting effect of living environment on dietary habits. Second, we obtained information on not only the frequency but also the portion size of food items, enabling us to estimate the amount of intake of food categories and nutrients. Third, participants were limited to recent mothers whose nutritional intake is important for their own selves and their infants.

This study indicates that after large-scale disasters, the nutritional intake of people in certain living environments will continue to deteriorate for a long period, even for recent mothers whose nutritional intake is important for their own health and the health of their infant. It is necessary to review the nutritional support provided for the people living in high-risk environments, like those who have moved to 'rental housing' or in a 'reconstructed home', and to reconsider the need for long-term reconstruction plans, for rehabilitation after a large-scale disaster and in preparation for future disasters.

In conclusion, our results suggest that the living environments long-term after large-scale disasters are associated with dietary habits and nutritional intake in recent mothers.

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