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[Review]

## Study of developmental disorders among newborns in Fukushima City after the Great East Japan Earthquake and nuclear power plant accident ; an adjunct study of the Fukushima Regional Center of the Japan Environmental and Children's Study (JECS)

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### Abstract

The present adjunct study of the Japan Environment and Children's Study (JECS) aimed to determine the occurrence of developmental disorders in Fukushima Prefecture, which was exposed to low-dose radiation. At two medical institutions in Fukushima City, we enrolled 339 pregnant women from September 2013 through May 31, 2014, who delivered 335 neonates (174 male, including one set of twins) between November 4, 2013 and November 11, 2014. The parents of four neonates declined to participate in the present study and one neonate died. Therefore, 334 families agreed to participate in additional surveys until March 2017. Child Behavior Checklists (CBCL) were mailed to all 334 families during the month of their infant's second birthday and we received 236 responses (response rate, 70%). All responses were below the 69<sup>th</sup> percentile in the CBCL, and no responses indicated significant problem behaviors. Boys tended to have higher values for items associated with developmental problems, but symptoms of autism were not evident. The mental health of the mothers indicated in the previous study might not have influenced the children. Autism spectrum disorder (ASD) is not obvious by the age of three years and thus it might become apparent as the children grow older.

**Key words :** neonate, developmental disorder, pediatric health, disaster, low-dose radiation

### Introduction

The Ministry of the Environment is conducting an ongoing nationwide birth cohort investigation of 15 regions in Japan called the Japan Environment and Children's Study (JECS)<sup>1)</sup> to determine how environmental factors affect the growth and development of children. The investigation aims to elucidate environmental factors to realize a healthy environment for growth and development, so parenting can proceed with confidence<sup>2,3)</sup>. Effects of the Great East Japan Earthquake and subsequent nuclear accident at the Fukushima Daiichi Nuclear Power Plant are expected to persist over the long term and

to contribute to ongoing anxiety among local residents. A major long-term effect of the Chernobyl nuclear disaster on residents of affected areas has been the disruption of mental and physical processes<sup>4)</sup>, including anxiety regarding radiation, unexplained physical symptoms, and subjective health concerns<sup>5)</sup>. The study area in Fukushima was expanded on October 1, 2012 to include 59 municipalities throughout the prefecture<sup>2)</sup>.

Additional independent JECS surveys are conducted separately from the overall nationwide survey at centers in these municipalities. The present study aimed to determine relationships between the mental status and development of children in Fuku-

shima after the disasters of the Great East Japan Earthquake and nuclear accident that generated considerable environmental pollution. We also aimed to clarify the long-term biological effects of contamination with low-dose radioactivity on the incidence of developmental disabilities. However, because a prior study identified considerable psychosocial anxiety, we assessed whether caregiver anxiety affects developmental disorders<sup>5</sup>. Ito *et al.* reviewed 11 studies of the Fukushima Health Management Survey and reported that the Fukushima nuclear accident did not affect pregnancy outcomes, but did affect maternal mental health<sup>6</sup>. We also plan to determine psychological effects on child-rearing in areas of Fukushima Prefecture that were exposed to low doses of radiation in a future study.

## Methods

### *Study participants*

From two hospitals in Fukushima City (“A” and “B”), we recruited 227 and 112 pregnant women, respectively (339 in total) who were scheduled to deliver between November 4, 2013 and November 11, 2014.

All survey respondents were parents of the children. Therefore, the study cohort initially comprised 339 families defined as two parents and their children born after the disasters, recruited between September 2013 and May 31, 2014. Between November 4, 2013 and November 11, 2014, the recruited pregnant women delivered 335 neonates (174 males, including one set of twins, and 161 females). Four of them declined to participate in the study and one neonate died. Therefore, 334 families agreed to participate in additional surveys.

The Ethics Committee at Fukushima Medical University approved this study, which conformed to the ethical principles enshrined in the Declaration of Helsinki (2013). Informed consent from all participating families was documented in writing.

### *Surveyed items*

The Japanese version of Child Behavior Checklist (CBCL)/2-3 was mailed to the 334 families with a request that the parents return completed versions within two months. The CBCL is a reliable survey of the emotions, behavior and socialization of children and it comprises 99 questions and a free description section<sup>7</sup>. The CBCL/2-3 was applied because all the children surveyed in the present study were two years old.

Responses to mailed questionnaire items were evaluated as : not at all, somewhat applicable, or applicable ; these were converted into scores. We evaluated subscales of dependence, separation, withdrawal, anxious and nervousness, development, sleep/meals, aggressiveness, attention and concentration, and defiance. “Internalizing problem” is defined as the sum of dependence separation, withdrawal, anxious, and nervousness. “Externalizing problem” is defined as the sum of aggressiveness, attention and concentration, and defiance. The total score was the sum of all subscales. Higher scores indicated stronger tendencies.

The respondents to the questionnaires comprised parents who were raising the children.

### *Statistical analysis*

Summed scores were statistically analyzed using t-tests and SPSS 25 (IBM, Armonk, NY, USA). Nakata *et al.* used t-tests in their standardization of the Japanese version of CBCL<sup>8</sup>. In addition, the study of the prevalence of problem behavior among Dutch children by Koot and Verhulst using CBCL/2-3 also included statistical analysis as an interval/exceptional scale<sup>9</sup>. Thus, we considered our statistical analyses of responses to the CBCL/2-3 as an interval/proportional scale.

## Results

We received 236 (70%) responses to 335 mailed questionnaires. The children of the respondents were aged  $24.62 \pm 1.13$  [mean  $\pm$  SD] months.

### Table 1. Descriptive statistics of CBCL/2-3.

All responses were below the 69<sup>th</sup> percentile of the CBCL checklist subscale and within normal ranges. Serious child developmental problems were not reflected in the scores or in the free description.

### Table 2. Findings of t-tests by gender.

The results revealed a tendency towards a developmental difference among males, but it did not reach statistical significance ( $P = 0.056$ ).

The free response section aimed to identify the most worrisome concerns of the parents regarding their children. Some were concerned about the development of their children, but no concerns were raised about exposure to low-dose radiation.

Table 1. Descriptive statistics of CBCL

	N	Minimum	Maximum	Average	s.d.	Percentile
Dependent separation	236	0	11	2.57	2.38	≤50%
Withdrawal	236	0	10	0.91	1.31	≤50%
Anxious nervousness	236	0	8	1.14	1.51	≤50%
Development	236	0	6	0.36	0.81	≤69%
Sleep/meal	236	0	10	2.50	2.31	≤50%
Aggressiveness	236	0	15	3.67	3.00	≤69%
Attention concentration	236	0	8	2.29	1.82	≤50%
Defiance	236	0	27	6.95	5.55	≤50%
Internalizing problem	236	0	25	4.61	4.33	≤50%
Externalizing problem	236	0	45	12.91	9.04	≤50%
Total score	236	0	79	22.10	15.58	≤50%

Table 2. Findings of t tests, by gender.

		Average	s.d.	p
Dependent separation	Male	2.44	2.48	0.380
	Female	2.71	2.26	
Withdrawal	Male	0.96	1.43	0.504
	Female	0.85	1.16	
Anxious nervousness	Male	1.06	1.60	0.361
	Female	1.23	1.39	
Development	Male	0.46	0.98	0.056
	Female	0.26	0.53	
Sleep/meal	Male	2.56	2.25	0.696
	Female	2.44	2.38	
Aggressiveness	Male	3.74	3.06	0.669
	Female	3.58	2.95	
Attention concentration	Male	2.35	1.88	0.568
	Female	2.22	1.76	
Defiance	Male	6.64	5.55	0.359
	Female	7.31	5.56	
Internalizing problem	Male	4.46	4.63	0.549
	Female	4.79	3.99	
Externalizing problem	Male	12.74	9.31	0.758
	Female	13.10	8.76	
Total score	Male	21.92	16.24	0.849
	Female	22.31	14.87	

## Discussion

This cohort study proceeded in Fukushima Prefecture, which was affected by the Great East Japan Earthquake and subsequent nuclear accident. We found no evidence of behavioral problems among children born two or three years after the disaster. Fujimori *et al.* reported that pregnancy and birth survey data after this disaster did not seem to indicate significant adverse outcomes throughout Fukushima Prefecture<sup>10</sup>. However, Goto *et al.* reported that 28% of women in Fukushima Prefecture who had registered pregnancies between August 1, 2010 and July 31, 2011 screened positive for depressive symptoms<sup>11</sup>. Ishii *et al.* reported that the findings from the first four years of the Pregnancy and Birth Survey in Fukushima Prefecture suggested that the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident had affected the mental, rather than physical, health of mothers<sup>12</sup>. Several reports have described that the mental health of pregnant women worsened in Fukushima Prefecture after the disaster<sup>12</sup>, but the present results do not show behavioral problems among children who were born two or three years after the disaster. Thus, maternal mental health status might not have affected their offspring.

The present findings uncovered a tendency regarding development in males. Notably, ASD is more common in males as an extreme manifestation of male cognitive patterns<sup>13</sup>. Biological mechanisms that might account for male bias in terms of development included theories regarding the effects of fetal testosterone, X and Y chromosomes and reduced autosomal penetrance<sup>13</sup>. Moreover, we could not confirm either the age of the respondents or the impact of their occupations. Parents are thought to be aware of autism by the time their children reach the age of two years, whereas ASD becomes evident later<sup>14</sup>. The present survey did not identify any children who had been taken to a psychiatric consultation and the outcome was not clear from the results. Clinical diagnoses of pervasive developmental disorder (PDD) and Asperger syndrome are replacing those for ASD at the age 20 months because tests for ASD lack sensitivity at that age according to the Autism Diagnostic Interview-Revised<sup>15</sup>. A diagnosis of autism at the age of two years is more stable than a diagnosis of PDD-not otherwise specified (NOS) at the same age<sup>16</sup>. The present survey targeted only children aged 24 months, and thus ASD might become apparent in future surveys.

A cross-sectional study of children aged two to three years by Nakata *et al.* identified a significant sex difference associated with aggressiveness. The present findings might have differed from theirs because we focused only on children aged two years<sup>8</sup>.

The survey results for all items were within normal ranges. Therefore, evidence of obvious developmental disorders was not found, indicating that their incidence did not increase among children born to mothers in Fukushima City who had been exposed to low-dose radiation during the disaster. No respondents raised concerns about low-dose radiation exposure. However, support might be required in the future as the infants mature.

One limitation of the present study is the small cohort. Another is that the responses to questionnaire depended on descriptions provided by the parents, and thus the actual degree of developmental problems might not be accurately reflected.

## Conclusions

We found no evidence of an increase in the incidence of developmental disorders among two-year-old infants born in Fukushima City after it was exposed to low-dose radiation. The mental status of mothers who lived in Fukushima Prefecture at the time of the disaster does not seem to have affected their children. Because symptoms of developmental disorders in the children might emerge as they grow older, a follow-up survey should be implemented.

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### Conflict of interest disclosure

None of the authors have any conflicts of interest to disclose.

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