RESEARCH ARTICLE

General Workers Living with Younger Children in Fukushima Performed more Preventive Behavior against Radiation during and after the Nuclear Disaster

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Abstract

Background: During and after the Fukushima nuclear disaster (FND), many parents were concerned about the effects of radiation on the health of their children. Purpose: To clarify the factors that influenced general workers living with children and the effect of child age groups in implementing preventive behaviorsagainst radiation following the FND. Materials and Methods: A descriptive study of preventive behaviors among general workers was carried out 3-5 months after the nuclear disaster. The subjects were 1,394 regular workers, who took part in radiation seminars run by the Fukushima Occupational Health Promotion Center between July and September, 2011. In total, 1,217 responses were submitted, of which 1,110 were eligible for the present study. This anonymous questionnaire survey inquired about the presence and age of children in the household and about radiation preventive behavior implemented after the FND. The contribution of each variable was assessed by logistic regression analysis. Results: General workers in Fukushima who lived with younger children performed more preventive behavior against radiation during and after the FND. In particular, both location-related and daily routines were practiced significantly more frequently ($p<0.01$) by workers living with a child in the age ranges of 0-6 (8 of 10 items) and 7-12 (5 of 10 items). Conclusions: This is the first study to assess the positive association between living with children by age group and increased preventive behavior against radiation implemented by general workers after the FND.

Keywords: Living with children - preventive behavior - nuclear disaster - radiation - Fukushima

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Introduction

The potential effects of radiation worried many people living in Fukushima after the Fukushima Dai-ichi nuclear power plant accident, which occurred after the earthquake and tsunami of March 11, 2011. These natural disasters disabled both the electrical power systems and reactor cooling systems. During the accident, multiple reactor meltdowns resulted in the release of radiation due to hydrogen explosions and the opening of the pressure valves of the nuclear reactor containment vessels (Wakeford, 2011), which has since contaminated areas throughout Fukushima prefecture and other parts of Eastern Japan (Normille, 2011). Previous studies following the Chernobyl accident reported cancer and carcinogenic risks that increase with increasing environmental radiation exposure even at low radiation doses (Tsujimoto and Kusama, 1994; Iida, 1996). Busby reported that even very low dose radiation exposure increased infant leukemia after Chernobyl (Busby, 2009). Soon after the Fukushima's accident, both the Nuclear and Industrial Safety Agency, a Japanese government organization, and the Fukushima prefectural government disseminated information calling for residents to implement radiation preventive behaviors such as refraining from going outside, rigorous enforcement of hand-washing and gargling, brushing dirt off clothing after returning home, and wearing a mask when leaving the home (Nuclear and Industrial Safety Agency, 2011; Fukushima Prefectural Government, 2011).

Many of those affected by the Fukushima nuclear disaster (FND) have been forced to live as evacuees, having lost their homes due to earthquake and tsunami damage, or from living within the 20 km evacuation zone. In addition to those who lived within the mandatory evacuation area, many households with children evacuated voluntarily and took refuge in other prefectures due to radiation-related concerns regarding the health of their children (Ministry of Internal Affairs and Communications, 2011). Workers who remained in Fukushima after the FND, especially those living with children, have been forced to cope with issues related to radiation exposure. In an attempt to minimize their exposure, workers in Fukushima have

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taken preventive measures, such as wearing masks and refraining from going outside. Thus far, however, there have been no studies to investigate whether living with a child and/or child's age group influenced the implementation of preventive behaviors among general workers after a nuclear disaster.

This present study attempts to clarify the extent to which the age groups of children in the households of general workers in Fukushima influenced their implementation of preventive behaviors against radiation. Our aim is to provide information that may help with the nuclear disaster education and training of people with children who live near nuclear power plants.

Materials and Methods

Subjects

This study design was a cross-sectional questionnaire survey that was distributed to regular workers at seminars on radiation and health, which were held between June and August, 2011 (3-5 months after the FND) and were hosted by the Fukushima Occupational Health Promotion Center (FOHPC) or under the joint auspices of the FOHPC and local companies. One of the official roles of the FOHPC is to provide health and safety assistance to workers and industrial health professionals throughout Fukushima prefecture. From May to August, 2011, the FOHPC notified workers of the seminars through their website and a pamphlet irrespective of the industry in which they were employed. Some companies applied to the FOHPC so that they would be able to take part in a seminar. The FOHPC gave seminars to companies that had applied, either by visiting the companies by holding a joint seminar with employees from several companies. The companies that participated included companies those were highly concerned with worker health before the FND. Anonymous questionnaires were distributed to all attendees by FOHPC staff members. Attendees completed the questionnaires and they were collected before the start of each seminar. The subjects of the present study were people who took part in one or more of these radiation seminars and completed a questionnaire. Prior to distribution, participants who took part in multiple seminars were asked to avoid replying more than once. All participants gave informed consent regarding the release of information for the study. This study was reviewed and approved by the FOHPC.

Outcomes

There were two parts to the questionnaire: the first asked for biographical and background information such as gender, age range, and whether the subject evacuated, was living with someone who is pregnant, the industry in which they were employed, and their current area of residence. The areas of residence were divided into three area categories based on their proximity to the Fukushima Dai-ichi Nuclear Power Plant: 20-40 km (coastal region); 40-80 km (central region); and more than 80 km (mountainous region). The area within 20 km of the power plant, which is also part of the coastal region, was excluded from the coastal region category because its residents were subject to mandatory evacuation.

The survey asked the respondents to select their age from one of five categories: <30, 30-39, 40-49, 50-59, and >60. Respondents were also asked whether they lived with children or teenagers. If they did, they were then asked to state the age range of the children or teenagers in their household from 6 age categories: newborn (<1 year); infant-kindergarten (1-6 years); elementary school (7-12 years), junior high school (13-15 years); senior high school (16-18 years) and above high school (19 years).

Due to the small number of respondents with newborns (N=27), the newborn age category was added to the infant-kindergarten age group. Similarly, due to the small number of respondents with 19-year-old children (N=6), the above high school age category was added to the high school age category.

The age categories that remained for analysis were thus reduced to three groups: 0-6, 7-12, and 13-19. When responses included multiple categories, the responses were counted in each category. Respondents who were not living with any children were used as the control group.

The second part of the questionnaire asked subjects about the types of preventive behaviors they practiced during and after the nuclear disaster. The list contained a total of 10 preventive behaviors: keeping track of environmental radiation levels using news sources such as newspapers; hand-washing and gargling every day; wearing a mask when leaving the home; buying bottled water; refraining from going outside; not purchasing local agricultural products; brushing dirt off clothing after returning home; spending more time in areas within Fukushima with lower levels of radiation; evacuating family members to areas of lower radiation; and spending more time in prefectures outside of Fukushima. Respondents were asked to indicate all of the behaviors that they had practiced during and after the FND.

Statistical analysis

Chi-square and Mantel-Haenszel tests were used to compare the frequency of behaviors between the control group and those living with children by child's age group. Multiple logistic regression analysis was used to assess the contribution of living with a child in each of the three age groups to preventive behaviors that respondents practiced, adjusted by respondent's age group, living with a pregnant woman, and industry of employment. The Statistical Package for the Social Sciences (SPSS Japan Inc. version 16.0J, Tokyo, Japan) was used for all analyses. All probability values were two-tailed and at a 95% level of significance.

Results

In total, 41 seminars were held, and 1,394 workers were given information on radiation and health. The response rate in this study was 87.3% (1,217 responses from the 1,394 participants). Of the 1,217 responses, 107 responses were ineligible because they did not contain all of the data needed for analysis, leaving a total of 1,110 eligible responses for an eligible response rate of 79.6%. The control group was comprised of 615 respondents

who were not living with any children. The numbers of respondents with a child in the 0 – 6- 7 – 12 and 13-19 age groups were 162, 215, and 267, respectively.

Table 1 shows the characteristics of workers living with children by child's age group and the control group. A chi-square test found a statistically significant difference in the age of respondents with a child in each of the age groups and the control group; the respondents with a child were younger ($p<0.01$). Respondents with a child in the 0-6 age group lived with a pregnant woman more frequently than those in the control group ($p<0.05$). There was also a statistically significant difference in the industry of employment of respondents with a child in the 13-19 age group and the control group ($p<0.05$).

Table 2 shows a comparison of prevalence of preventive behaviors for radioactive contamination between workers living with a child by child's age group and control. Respondents with a child in the 0-6 age group and the 7-12 age group were significantly more likely to employ almost all of the preventive behaviors than the control group. Among workers with a child in the 0-6 age group, the statistical significance for 7 out of the 10 behaviors

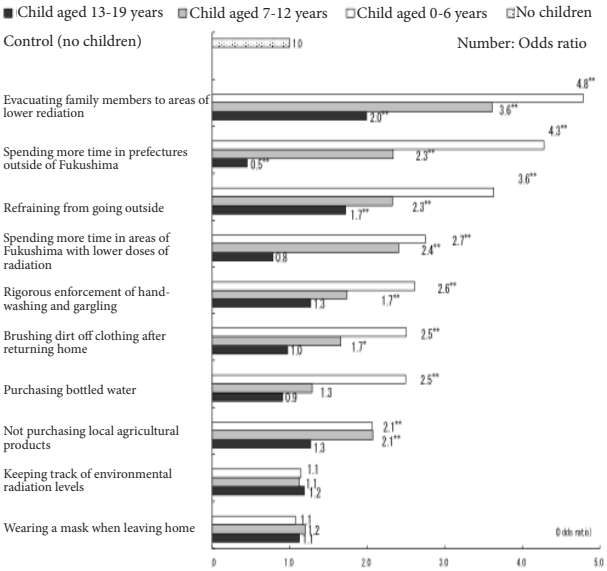

Figure 1. Odds Ratios of Living with Children by Child's Age Group for Each Preventive Behavior against Radiation Following the Fukushima Nuclear Disaster

Table 1. Characteristics of Workers with Children and Those Without Following the Fukushima Nuclear Disaster

		No children (control) (N=615)	0-6 years (N=162)	Child aged 7-12 years (N=215)	13-19 years (N=267)
Female workers		148 (24.1%)	32 (19.8%)	57 (26.5%)	86 (32.2%)
Age Category	≤30	77 (12.6%)	14 (8.6%)**	4 (1.9%)**	15 (5.6%)**
	30-39	87 (14.1%)	75 (46.3%)	83 (38.6%)	26 (9.7%)
	40-49	98 (15.9%)	36 (22.2%)	96 (44.7%)	152 (56.9%)
	50-59	253 (41.1%)	28 (17.3%)	17 (7.9%)	64 (24.0%)
	≥60 over	100 (16.3%)	9 (5.5%)	15 (6.9%)	10 (3.8%)
Evacuation status	Mandatory	5 (0.8%)	3 (1.9%)	3 (1.4%)	1 (0.4%)
	Voluntary	4 (0.7%)	1 (0.6%)	1 (0.5%)	0 (-)
	Did not evacuate	606 (98.5%)	158 (97.5%)	211 (98.1%)	266 (99.6%)
Living with a pregnant woman		15 (2.4%)	14 (8.6%)*	4 (1.9%)	2 (0.7%)
Workers living with children or teenagers		418 (45.6%)	418 (45.6%)	418 (45.6%)	74 (38.3%)
Industry of employment	Construction	128 (20.8%)	37 (22.8%)	44 (20.5%)	39 (14.6%)*
	Manufacturing	246 (40.0%)	69 (42.6%)	100 (46.5%)	127 (47.6%)
	Others	241 (39.2%)	56 (34.6%)	71 (33.0%)	101 (37.8%)
Proximity of current residence to FDNPP					
	20-40 km (coastal region)	123 (20.0%)	22 (13.6%)	37 (17.2%)	40 (15.0%)
	40-80 km (central region)	411 (66.8%)	126 (77.8%)	149 (69.3%)	188 (70.4%)
	>80 km (mountainous region)	81 (13.2%)	14 (8.6%)	29 (13.5%)	39 (14.6%)

*p values were <0.05 for chi-square test compared with workers who were not living with any chiledren; **p values were <0.01 for chi-square test compared with workers who were not living with any chiledren; ***FDNPP, Fukushima Dai-ichi Nuclear Power Plant

Table 2. Characteristics of Workers with Children and Those Without Following the Fukushima Nuclear Disaster

	No children (control) (N=615)	0-6 years (N=162)	Child aged 7-12 years (N=215)	13-19 years (N=267)
Daily-routine behaviors				
Keeping track of environmental radiation levels through sources such as newspapers	362 (58.9%)	92 (56.8%)	125 (58.1%)	164 (61.4%)
Wearing a mask when leaving home	191 (31.1%)	51 (31.5%)	75 (34.9%)	88 (33.0%)
Rigorous enforcement of hand-washing and gargling	189 (30.7%)	78 (48.1%)**	88 (40.9%)**	94 (35.2%)
Purchasing bottled water	149 (24.2%)	70 (43.2%)**	62 (28.8%)	60 (22.5%)
Refraining from going outside	108 (17.6%)	63 (38.9%)**	65 (30.2%)**	66 (24.7%)*
Brushing dirt off clothing after returning home	71 (11.5%)	35 (21.6%)**	35 (16.3%)	29 (10.9%)
Location-related behaviors				
Not purchasing local agricultural products	69 (11.2%)	34 (21.0%)*	44 (20.5%)**	35 (13.1%)
Spending more time in areas of Fukushima with lower levels of radiation.	57 (9.3%)	34 (21.0%)**	41 (19.1%)**	20 (7.5%)
Spending more time in prefectures outside of Fukushima	41 (6.7%)	37 (22.8%)**	31 (14.4%)**	9 (3.4%)*
Evacuating family members to areas of lower radiation	36 (5.9%)	32 (19.8%)**	35 (16.3%)**	25 (9.4%)*

*p values were <0.05 for Mantel-Haenszel test adjusted by age category compared with workers who were not living with any children; **p values were <0.01 for Mantel-Haenszel test adjusted by age category compared with workers who were not living with any children

was p<0.01 and one was p<0.05. The difference between respondents with a child in the 0-6 age group and control was also quite marked, with 6 behaviors showing a p<0.01 difference In contrast, respondents with a child in the 13-19 age group practiced only 2 behaviors with greater frequency than those in the control group: refraining from going outside and evacuating family members to areas of lower radiation (p<0.05 for both behaviors). Interestingly, respondents with a child in the 13-19 age group were less likely to spend time in prefectures outside of Fukushima than respondents in the control group (p<0.05).

Figure 1 shows odds ratios for each of the 10 preventive behaviors by child's age group as determined by logistic regression analysis. There was a positive association between living with a child in the 0-6 age group and the performance of all but 2 behaviors: keeping track of radiation levels and wearing a mask when leaving home. Respondents with a child in the 7-12 age group were found to practice 6 behaviors than those in the control group: evacuating family members to lower radiation area, spending more time in prefectures outside of Fukushima, refraining from going outside, spending more time in areas of Fukushima with lower levels of radiation, rigorous enforcement of hand-washing and gargling, and brushing dirt off clothing after returning home. In contrast, respondents with a child in the 13-19 age group were more likely to practice only 2 more preventive behaviors than those in the control group: evacuating family members to lower radiation area and refraining from going outside.

Discussion

The present study suggested that during and after the FND, general workers who lived with younger children in Fukushima practiced preventive behaviors against radiation more frequently than those without children. Specifically, location-related and daily-routine behaviors were more likely to be performed by workers living with a child aged between 0 and 12. We clarified that workers who lived with younger children avoided cancer and carcinogenic risks that increase with increasing radiation exposure even at low radiation doses. To our knowledge, this is the first study in the literature to assess the positive association living with children by each age group and the practice of preventive behaviors against radiation among general workers after a nuclear disaster.

We found that living with a younger child was associated with performing a greater number of preventive behaviors. A possible explanation for this association is that adults living with younger children are acting in the same manner as they instruct their children to act in order to minimize the amount of radiation to which their children are exposed. According to Fujiwara et al. (2000), children generally have a greater sensitivity to radiation than adults. As a result, it is said that the younger the person is when they are exposed to radiation, the higher the likelihood that it will adversely affect his or her health (Fujiwara et al., 2000). The impact of age is particularly noticeable in children, who have an increased risk of developing a number of conditions including radiation cataracts, leukemia, cancer, parathyroid adenoma, and hyperparathyroidism. Studies of atomic bomb survivors in Hiroshima found that in the cases of cancer and leukemia, age at the time of radiation exposure affected both the early and temporal risks for radiation-related conditions. Exposure at a younger age was associated with higher early risk and a greater drop in in later temporal risks. It has also been suggested that radiation exposure prior to puberty could result in decreased height and weight (Otake et al., 1994). Thus the preventive behaviors practiced by adults living with children, which aim to reduce the internal and external radiation exposure of their children, can be considered appropriate.

Living with a younger child (aged 0-12) was associated with a number of location-related behaviors performed after the FND, such as evacuating family members to lower radiation areas, spending more time in prefectures outside of Fukushima, refraining from going outside, and spending more time in areas of Fukushima with lower levels of radiation. The performance of 2 behaviors: evacuating family members to areas of lower radiation and refraining from going outside, was statistically higher in workers living with children of each of the age groups than it was in the control group. Furthermore, workers who lived with a child between the ages of 0 and 12 had a greater tendency to spend time in areas with lower levels of radiation, (whether inside or outside Fukushima). Generally, the influence of scattered radiation is inversely proportionate to square of the distance (Boice, 2006), thus the influence of radiation decreases exponentially as distance increases. As noted above, children are more sensitive to radiation than adults. As such, spending time in areas with lower doses of radiation can greatly reduce external radiation exposure. It is thought that these location-related behaviors were appropriate actions for the prevention of radiation-related health effects in the human body. While refraining from going outside does not prevent external radiation exposure altogether, it is considered to have a limiting effect in that it prevents unnecessary external exposure. Our results suggested that after the FND, in order to reduce the external radiation to which their children were exposed, parents of younger children sought to increase their geographic distance from the radiation-contaminated area. We would consider this to be prudent behavior following a nuclear accident.

We also found that in comparison with the control group, living with a child between the ages of 0 and 6 was associated with higher performance of daily-routine behaviors such as hand-washing and gargling, brushing dirt off clothing, purchasing bottled water and not purchasing local agricultural products. Similarly, living with a child aged between 7 and 12 was associated with higher performance of hand-washing and gargling, brushing dirt off clothing, and not purchasing local agricultural products. In contrast, workers who lived with a child aged between 13 and 19 enacted the same preventive behaviors as the control group. All of the daily-routine behaviors seek to prevent internal radiation exposure. It is well-known that the long-term health consequences of internal radiation exposure are greater for humans than those of external radiation exposure (Busby, 2009). This result showed that workers in Fukushima who lived with

a child aged 0-12 sought to prevent internal radiation exposure through the implementation of a number of daily-routine behaviors.

Our study clarified that the general workers in Fukushima who lived with younger children performed a greater number of appropriate daily-routine and location-related preventive behaviors in order to limit internal and external radiation exposure in the FND. Thus, it suggests the importance that families who live with younger children near nuclear power plants are given training and education on appropriate preventive behaviors against radiation that they can perform in the event of a nuclear accident. Preparedness training and education for residents with younger children, which includes the teaching of appropriate behaviors for limiting or preventing unnecessary exposure, may help to limit the level of harmful radiation to which they are exposed. The monitoring of environmental radiation levels, in particular, would seem to be important for allowing residents to move to areas with lower levels of radiation and to identify places of refuge in the event of a nuclear disaster and limit external exposure. The results regarding the daily behaviors of families with younger children suggest that the storage of water, food and clothes would be useful in the avoidance of internal exposure. Moreover, the results suggest that families with younger children should be given greater priority when supplies are distributed during and after a nuclear disaster.

In contrast to our findings on workers with a child in the 0-12 age group, we found little difference between respondents with a child in the 13-19 age group and the control group. We can surmise several reasons for this result. First, parents living with teenagers tend to treat their children as adults. Previous studies have reported that adolescents are known to act as well as adults in the emergency settings (Jones, 2008). Second, there might be a role-sharing arrangement in a family during emergency situations. It seemed that the children of high school age might be given the role of acquiring further information on safety and living by themselves, while the parent(s) might be tasked with other duties to support family life. Further analysis could help to elucidate some of these family relationship dynamics that take place when families are responding to disaster situations.

This study suggested that spending more time in prefectures outside of Fukushima was inversely associated with living with teenagers. A possible reason for this is that teenagers did not want to leave the Fukushima area. Since teenagers have begun to gain independence from their parents, some of the behaviors that they perform in the disaster period may be contrary to the intentions of their parent(s). While the exact reasons are unclear, further studies that focus on the nuclear disaster response behavior of parents with teenagers would be an interesting topic for future research.

There are some limitations in the present study. First, our study uses a cross-sectional design, which does not prove a causal relationship. Secondly, these results include a selection bias and an eventual bias because the study target was limited to the participants of the radiation seminars. These limitations must be taken into consideration when interpreting our results. Finally, the results may underestimate the preventive behaviors practiced, because the responses were counted in a single age group when they extended to multiple age groups.

In conclusion, we clarified that among general workers in Fukushima, there was a positive association between living with younger children and performing a greater number of preventive behaviors against radiation after the FND. The results of this study are significant, as they provide an objective view of the individual actions that general workers in Fukushima undertook to protect themselves and their families from radiation exposure during and after the FND. Our results provide information that may help with the education and training for nuclear disaster preparedness for those who live near nuclear power plants.

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