

with as few adverse events as treatment of hypertension with thiazides, we would support statin treatment in this group.

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## RESEARCH LETTERS

### Psychological Distress in Workers at the Fukushima Nuclear Power Plants

**To the Editor:** A magnitude 9.0 earthquake and tsunami on March 11, 2011, triggered plant explosions and a nuclear meltdown at the Fukushima Daiichi nuclear power plant. The nearby Daini nuclear power plant also experienced dam-

age but remained intact. Studies after the nuclear disaster at Chernobyl<sup>1</sup> suggest nuclear power plant workers are at risk for general psychological distress, including posttraumatic stress response (PTSR). We examined the psychological status of Fukushima workers 2 to 3 months after the disaster.

**Methods.** Following approval by the ethics committees of Ehime University and National Defense Medical College, we recruited all full-time nuclear power plant workers from the Daiichi (n=1053) and Daini (n=707) plants in May and June 2011. Written informed consent was obtained.

Using a self-report questionnaire, we assessed sociodemographic characteristics and disaster-related experiences (TABLE 1; coded dichotomously as "yes" or "no"), including discrimination/slurs (*sabetsu/chuushou*) because the electric company was criticized for their disaster response and the workers have been targets of discrimination.<sup>2</sup> General psychological distress was evaluated using the K6 scale (Japanese version),<sup>3</sup> including items on feeling nervous, hopeless, restless/fidgety, depressed, everything was an effort, and worthless in the last 30 days. Scores ranged from 0 to 24, with 13 or higher indicating high distress.<sup>3</sup> PTSR was assessed by the Japanese version of the Impact of Event Scale Revised (IES-R-J), a 22-item scale including PTSR domains of intrusion, avoidance/numbing, and hyperarousal.<sup>4</sup> Scores ranged from 0 to 88, with 25 or higher indicating high PTSR.<sup>4</sup> Cronbach  $\alpha$  was high for K6 (0.88) and IES-R-J (0.95).

**Table 1.** Participant Characteristics, General Psychological Distress (GPD), and Posttraumatic Stress Responses (PTSR)

Characteristics	Total (N = 1495)		Daiichi (n = 885)		Daini (n = 610)		P Value
	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	
Age, y							
20-39	728		429		299		
40-59	743	39.6 (11.3) <sup>a</sup>	446	39.6 (11.3) <sup>a</sup>	297	39.5 (11.3) <sup>a</sup>	.39
$\geq 60$	18		8		10		
Male sex <sup>b</sup>	1412	94.4 (93.3-95.6)	853	96.4 (95.2-97.6)	559	91.6 (89.4-93.8)	<.001
Supervisory work status	153	10.2 (8.7-11.8)	89	10.1 (8.1-12.0)	64	10.5 (8.1-12.9)	.78
Preexisting illnesses <sup>b</sup>	217	14.5 (12.7-16.3)	135	15.3 (12.9-17.6)	82	13.4 (10.7-16.1)	.32
Discrimination/slurs <sup>b</sup>	191	12.8 (11.1-14.5)	124	14.0 (11.7-16.3)	67	11.0 (8.5-13.5)	.08
Near-death experience <sup>b</sup>	623	41.7 (39.2-44.2)	470	53.1 (49.8-56.4)	153	25.1 (21.6-28.5)	<.001
Tsunami evacuation <sup>b</sup>	185	12.4 (10.7-14.0)	87	9.8 (7.9-11.8)	98	16.1 (13.2-19.0)	<.001
Witnessing of plant explosions <sup>b</sup>	388	26.0 (23.7-28.2)	318	35.9 (32.8-39.1)	70	11.5 (8.9-14.0)	<.001
Family member deaths	87	5.8 (4.6-7.0)	53	6.0 (4.4-7.6)	34	5.6 (3.8-7.4)	.73
Colleague deaths <sup>b</sup>	259	17.3 (15.4-19.2)	173	19.5 (16.9-22.2)	86	14.1 (11.3-16.9)	.007
Major property loss <sup>b</sup>	433	29.0 (26.7-31.3)	285	32.2 (29.1-35.3)	148	24.3 (20.9-27.7)	.001
Home evacuation <sup>b</sup>	999	66.8 (64.4-69.2)	617	69.7 (66.7-72.7)	382	62.6 (58.8-66.5)	.004
High GPD, K6 $\geq 13$ <sup>c,d</sup>	638	42.7 (40.2-45.2)	412	46.6 (43.3-49.8)	226	37.0 (33.2-40.9)	<.001
High PTSR, IES-R-J $\geq 25$ <sup>c,e</sup>	378	25.3 (23.1-27.5)	261	29.5 (26.5-32.5)	117	19.2 (16.1-22.3)	<.001

Abbreviations: IES-R-J, Japanese version of the Impact of Event Scale Revised; K6, Japanese version of the K6 scale.

<sup>a</sup>Mean (SD) values are presented.

<sup>b</sup>Marked variables were entered in the multivariable logistic regression model (forced entry method) as potential outcome factors.

<sup>c</sup>Participants with missing data were excluded from the analysis.

<sup>d</sup>Data were missing for 10 participants (0.7% of total; Daiichi, n=6; Daini, n=4).

<sup>e</sup>Data were missing for 70 participants (4.7% of total; Daiichi, n=42; Daini, n=22).

Two-tailed  $\chi^2$  tests were performed to evaluate the difference in proportions. Significant independent variables from bivariate analysis were considered potential factors of high general psychological distress and PTSD, and were entered in the multivariable logistic regression model (forced entry method). SAS version 9.2 (SAS Institute) was used. A 2-sided  $P < .05$  was used to indicate significance.

**Results.** Of 1760 eligible workers, 1495 (85%) participated (Daiichi:  $n=885$  [84%]; Daini:  $n=610$  [86%]). Compared with Daini workers, Daiichi workers were more often exposed to disaster-related stressors (Table 1). Experiencing discrimination or slurs was not statistically significantly different between groups (14% vs 11%,  $P=.08$ ).

Daiichi workers had significantly higher rates of psychological distress ( $n=412$ ; 47%; 95% CI, 43%-50%; vs  $n=226$ ; 37%; 95% CI, 33%-41%;  $P < .001$ ) and PTSD ( $n=261$ ; 30%; 95% CI, 27%-33%; vs  $n=117$ ; 19%; 95% CI, 16%-22%;  $P < .001$ ) (Table 1). For both groups, discrimination or slurs were associated with high psychological distress (Daiichi: adjusted odds ratio [AOR], 2.06; 95% CI, 1.34-3.16; vs Daini: AOR, 2.90; 95% CI, 1.63-5.17) and high PTSD (Daiichi: AOR, 2.17; 95% CI, 1.43-3.30; vs Daini: AOR, 2.70; 95% CI, 1.47-4.96) (TABLE 2). Other significant associations in both groups

included tsunami evacuation and major property loss with psychological distress and preexisting illness and major property loss with PTSD.

**Comment.** We found that general psychological distress and PTSD were common in nuclear plant workers 2 to 3 months after the disaster. The prevalence was higher than in other studies (12.5% with severe or very severe psychological impairment in a review of 24 studies),<sup>5</sup> possibly due to the complexity of their experience. Higher rates were found among workers of Daiichi than Daini, which is concordant with their higher exposure to disaster-related stressors.

This is the first study to our knowledge to explore discrimination as a factor in postdisaster mental health. Experiencing discrimination was associated with both general psychological distress and PTSD. A similar phenomenon was observed in Vietnam War veterans; along with combat exposure, insufficient societal support and societal rejection upon homecoming were associated with posttraumatic stress disorder.<sup>6</sup>

Several limitations warrant discussion. Our report was cross-sectional, with neither baseline measures nor long-term outcomes. The responses were self-reported and no comparison group was available. We had no information on specific previous physical/mental illness; educational,

**Table 2.** Factors Associated With High General Psychological Distress (GPD) and High Posttraumatic Stress Responses (PTSR)

Mental Health Outcome Factors <sup>a</sup>	Daiichi (n = 885)				Daini (n = 610)			
	$\beta$	SE	Adjusted OR (95% CI)	P Value	$\beta$	SE	Adjusted OR (95% CI)	P Value
High GPD <sup>b</sup>								
Sex, female vs male	0.53	0.40	1.69 (0.77-3.73)	.19	0.53	0.32	1.70 (0.90-3.19)	.10
Preexisting illnesses	0.23	0.21	1.26 (0.84-1.89)	.26	0.72	0.26	2.05 (1.23-3.41)	.006
Discrimination/slurs	0.72	0.22	2.06 (1.34-3.16)	.001	1.07	0.29	2.90 (1.63-5.17)	<.001
Near-death experience	0.63	0.16	1.89 (1.39-2.56)	.001	0.21	0.22	1.24 (0.80-1.91)	.33
Tsunami evacuation	0.63	0.26	1.87 (1.13-3.09)	.015	0.59	0.25	1.80 (1.09-2.95)	.02
Witnessed plant explosion	0.03	0.16	1.03 (0.75-1.41)	.87	0.88	0.28	2.40 (1.39-4.14)	.002
Colleague deaths	0.17	0.19	1.19 (0.82-1.72)	.37	-0.11	0.27	0.90 (0.53-1.51)	.68
Major property loss	0.63	0.16	1.88 (1.38-2.58)	<.001	0.60	0.21	1.83 (1.21-2.77)	.004
Home evacuation	0.42	0.16	1.52 (1.10-2.08)	.01	0.05	0.19	1.05 (0.72-1.53)	.80
High PTSD <sup>c</sup>								
Sex, female vs male	0.56	0.41	1.74 (0.79-3.86)	.17	1.24	0.35	3.46 (1.76-6.81)	<.001
Preexisting illnesses	0.49	0.21	1.64 (1.08-2.48)	.02	0.79	0.29	2.20 (1.24-3.92)	.007
Discrimination/slurs	0.78	0.21	2.17 (1.43-3.30)	<.001	1.00	0.31	2.70 (1.47-4.96)	.001
Near-death experience	0.52	0.17	1.68 (1.20-2.34)	.002	0.53	0.25	1.70 (1.04-2.79)	.03
Tsunami evacuation	0.31	0.25	1.36 (0.84-2.22)	.21	0.98	0.28	2.67 (1.55-4.58)	<.001
Witnessed plant explosion	0.21	0.17	1.23 (0.89-1.72)	.21	-0.06	0.34	0.94 (0.49-1.84)	.87
Colleague deaths	0.40	0.19	1.49 (1.02-2.18)	.04	-0.11	0.33	0.89 (0.47-1.69)	.73
Major property loss	0.62	0.16	1.85 (1.34-2.56)	<.001	0.59	0.24	1.81 (1.12-2.91)	.02
Home evacuation	0.34	0.18	1.40 (0.99-1.99)	.06	-0.10	0.24	0.90 (0.57-1.44)	.67

Abbreviation: OR, odds ratio.

<sup>a</sup>Shown factors were entered in the multivariable logistic regression model (forced entry method).

<sup>b</sup>Defined according to the Japanese version of the K6 scale ( $\geq 13$ ). Data were missing for 10 participants (0.7% of total; Daiichi,  $n=6$ ; Daini,  $n=4$ ).

<sup>c</sup>Defined according to the Japanese version of the Impact of Events Scale-Revised ( $\geq 25$ ). Data were missing for 70 participants (4.7% of total; Daiichi,  $n=42$ ; Daini,  $n=22$ ).

marital, or socioeconomic status; or precise irradiation exposure, although irradiation symptoms were not reported.

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## Internal Radiation Exposure After the Fukushima Nuclear Power Plant Disaster

To the Editor: On March 11, 2011, an earthquake and tsunami struck Japan and led to a meltdown of the reactors at the Fukushima Daiichi nuclear power plant. Release of ra-

dioactive material into the air, water, and soil raised concern about internal radiation exposure and the long-term risk of cancer in nearby residents.<sup>1</sup> However, radiation exposure has not been measured.

**Methods.** Minamisoma is located 23 km north of the Fukushima Daiichi nuclear plant. Many residents were evacuated, but by August 2011, approximately half had returned. A voluntary screening program for levels of cesium (<sup>134</sup>Cs and <sup>137</sup>Cs), known to be representative of total internal radiation exposure,<sup>2</sup> was conducted between September 26, 2011, and March 31, 2012, for all residents aged 6 years or older using a whole-body counter (Fastscan Model 2250) shielded to background radiation. Detection limits were 210 Bq for <sup>134</sup>Cs and 250 Bq for <sup>137</sup>Cs with a 2-minute scan. Persons without radiation exposure would have a level of 0 Bq. Cesium exposure was measured as both total body exposure and concentration by body weight (Bq/kg) and is reported as median values with ranges (minimum to maximum). Total cesium exposure was converted into committed effective dose (sievert, Sv) based on the assumption of acute cesium inhalation immediately after the disaster in adults, and on that of chronic cesium ingestion after the disaster in children. Common dose-limit recommendations for the public are 1 mSv or less.<sup>3</sup>  $\chi^2$  Tests were used to compare proportions of adults and children exposed, with 2-sided  $P < .05$  considered statistically significant. All statistical analyses were conducted using Stata/MP version 11 (StataCorp LP). The institutional review board of the Institute of Medical Science, University of Tokyo, approved the study with a waiver of informed consent.

**Results.** A total of 9498 residents enrolled in the study, 24% of the registered population on August 15, 2011. The sample consisted of 1432 children (720 girls; median [range] age, 11 [6-15] years) and 8066 adults (4512 women; median [range] age, 44 [15-97] years).

A total of 3286 individuals (34.6%; 95% CI, 33.6%-35.6%) had detectable levels of cesium (FIGURE). Cesium was detected in 235 children (16.4%; 95% CI, 14.5%-18.3%), ranging from 210 to 2953 Bq (median, 590 Bq), with a concentration of 2.8 to 57.9 Bq/kg (median, 11.9 Bq/kg). In contrast, 3051 adults (37.8%; 95% CI, 36.8%-38.9%) had detectable levels of cesium, ranging from 210 to 12 771 Bq (median, 744 Bq), with a concentration of 2.3 to 196.5 Bq/kg (median, 11.4 Bq/kg). This difference in exposure risk between adults and children was statistically significant ( $\chi^2 = 246.5$ ,  $P < .001$ ).

Committed effective doses were less than 1 mSv in all but 1 resident (1.07 mSv).

**Comment.** To our knowledge, this is the first report on internal exposure to cesium radiation after the Fukushima Daiichi nuclear plant incident. In this sample, exposure levels were low in most adults and children tested and much lower than those reported in studies years after the Chernobyl incident (49 Bq/kg after 7-10 years).<sup>4</sup> Even the highest levels of contamination observed are below the thresh-