



Suicide Rates in Evacuation Areas After the Fukushima Daiichi Nuclear Disaster

A 5-Year Follow-Up Study in Fukushima Prefecture

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Abstract. *Background:* Associations between nuclear disasters and suicide have been examined to a limited extent. *Aim:* To clarify the suicide rates in evacuation areas after the nuclear disaster in Fukushima, which occurred in March 2011. *Method:* This descriptive study used monthly data from vital statistics between March 2009 and December 2015. Suicide rates in areas to which evacuation orders had been issued, requiring across-the-board, compulsory evacuation of residents from the entire or part of municipalities, were obtained and compared with the national average. *Results:* Male suicide rates in evacuation areas increased significantly immediately after the disaster, and then began to increase again 4 years after the disaster. Female suicide rates declined slightly during the first year and then increased significantly over the subsequent 3-year period. Moreover, male rates in areas where evacuation orders were issued for the total area declined over the course of approximately 2 years, but then began to increase thereafter. Analysis by age revealed postdisaster male rates in evacuation areas decreased for those aged 50–69 years and increased for those aged ≤ 29 years and ≥ 70 years. *Limitations:* The number of suicides among females and the female population in the evacuation area was small. *Conclusion:* Our findings suggest the need to keep in mind that, when providing post-disaster mental health services, suicide rates can eventually increase even if they initially decrease.

Keywords: disaster, epidemiology, mental health care, suicide, nuclear

The Great East Japan Earthquake, which occurred on March 11, 2011, was the largest earthquake ever recorded in Japan's history. The earthquake with a magnitude of 9.0 generated a massive tsunami and caused enormous damage to the Pacific Coast. This was followed by a separate tsunami, which hit the Fukushima Daiichi Nuclear Power Plant operated by the Tokyo Electric Power Company, causing radiation disasters in Fukushima Prefecture and requiring long-term evacuation of residents from many surrounding municipalities. Due to this triple disaster, more than 164,000 residents who lived near the nuclear power plant were forced to leave their homes at the direction of the Japanese government. These residents are still affected by ongoing evacuation, and almost 80,000 evacuees remain unable to return to their hometowns (as of February 2017; Fukushima Prefectural Government, Japan, 2017).

Devastating natural disasters and their aftermath cause psychological distress in affected individuals, although it does not necessarily equate to the development of a mental

illness. In Fukushima, the triple disaster – the earthquake, tsunami, and nuclear disaster – led to mandatory evacuation of people from the surrounding region, and residents were forced to relocate to non-evacuation areas and live under very stressful conditions, faced with separation from family members, loss of housing, and adjustment to new circumstances (Hyodo et al., 2010; Kiliç & Ulusoy, 2003; Suzuki et al., 2011; Wu et al., 2006). Psychological distress has been shown to be a major long-term health issue in a previous study following the Chernobyl nuclear accident (Bromet & Havenaar, 2007). Therefore, disaster mental health services have been made available in Fukushima on an ongoing basis based on experiences with past disasters (Kim, 2011; Takeda, 2011).

The association between nuclear disasters and suicide has been examined to a limited extent, that is, among clean-up workers in nuclear power plants (Loganovsky et al., 2008; Rahu, Rahu, Tekkel, & Bromet., 2006). While suicide rates in evacuation areas may serve as an important indicator of mental health status in evacuees after a

nuclear disaster, no study has examined changes in suicide rates in confined areas (i.e., evacuation areas), partly due to the rarity of such disasters. Moreover, it is difficult to collect suicide data in evacuation areas, as residents of these municipalities are scattered across the country after being forced to relocate outside the evacuation zone.

The present study aimed to examine changes in suicide rates in evacuation areas after the Fukushima nuclear disaster using vital statistics, including information such as predisaster addresses of evacuees. In addition, we hypothesized that evacuees from total evacuation areas (municipalities in which evacuation orders have been issued for the total area) might be more susceptible to mental health deterioration due to unpredictable radiation hazard regulations and uncertain prospects of livelihood, and that suicide rates would be higher in these areas. Our findings will be useful for the development of future policies on mental care activities for evacuees who are still affected by ongoing evacuation.

Method

Study Design

This descriptive study used monthly suicide data collected nationally as well as for each municipality in Fukushima Prefecture from March 2009 through December 2015. Data were obtained from vital statistics in Japan (Ministry of Health, Labour, and Welfare) and contained information such as age, sex, and address (certificate of residence) at the time of death. Official permission was obtained for the use of vital statistics from the Ministry of Health, Labour, and Welfare on the basis of Article 33 of the Statistics Act. The Japanese certificate of residence system is a registry of current residential addresses maintained by local governments in Japan. Under Japanese law, each resident's current address must be reported to the local government, which utilizes the information for tax, census, or vital statistics purposes. In the present study, it was possible to compare pre- and postdisaster suicide rates because vital statistics were recorded in the original municipalities before the disaster, unless the certificate of residence was updated after evacuation.

To calculate suicide rates, basic annual population data from the resident registry of each municipality (as of March 31, 2009–2015) were collected from the Ministry of Internal Affairs and Communications Statistics Bureau. This study was approved by the Ethics Committee of our institution.

Study Subjects

The Japanese government has designated evacuation areas according to spatial radiation dose rates as follows: (a) difficult-to-return areas, with a radiation dose rate of ≥ 50 millisieverts (mSv) per year; (b) residence restriction areas, with a radiation dose rate of ≥ 20 and < 50 mSv per year; and (c) areas where evacuation orders are ready to be lifted, with a radiation dose rate of < 20 mSv per year. The residents of these areas were forced to relocate to non-evacuation areas and were not allowed to stay overnight after the disaster. As for residence restriction areas and areas where evacuation orders are ready to be lifted, temporary entry is permitted (Ministry of Economy, Trade, and Industry, Government of Japan, Dec 20, 2013). Currently, difficult-to-return areas are still subject to protective measures, such as barricades, due to high spatial radiation dose rates.

In the present study, we targeted all three designated evacuation areas (i.e., difficult-to-return areas, residence restriction areas, and areas where evacuation orders are ready to be lifted) from which the residents had been forced to relocate. We defined (a) municipalities in which evacuation orders have been issued for the total area as “total evacuation areas,” and (b) municipalities in which evacuation orders have been lifted as of 2015, or have been issued partially, as “terminated/partial evacuation areas.” Under these definitions, Naraha Town, Tomioka Town, Okuma Town, Futaba Town, Namie Town, Katsurao Village, and Iitate Village were included in total evacuation areas, and Tamura City, Minami-Soma City, Kawamata Town, Hirono Town, and Kawauchi Village were included in terminated/partial evacuation areas (Figure 1 and Figure 2). Basic information regarding total evacuation areas and terminated/partial evacuation areas is provided in Table 1. The total population of these evacuation areas is approximately 188,000 (51,000 residents in total evacuation areas and 138,000 residents in terminated/partial evacuation areas). The total population of non-evacuation areas is 1.8 million. Raw data on the number of suicides and suicide rates in evacuation and non-evacuation areas (81-month period, March 2009 to December 2015) are shown in Table 2.

Data Analysis

Monthly suicide rates were calculated for each of the 12 municipalities designated as evacuation areas as well as non-evacuation areas by adding the monthly number of suicides in each municipality and dividing the total by the Basic Resident Register population. These values were then multiplied by 12 to obtain annual rates, as follows:



Figure 1. Evacuation areas (total and terminated/partial evacuation areas) designated after the Fukushima nuclear disaster

Notes. The tsunami generated by the Great East Japan Earthquake hit the Fukushima Daiichi Nuclear Power Plant, causing a nuclear disaster in Fukushima Prefecture. The location of the Fukushima Daiichi Nuclear Power Plant is circled. Regions colored in dark gray correspond to municipalities where evacuation orders were issued for the total area (total evacuation areas: Naraha, Tomioka, Okuma, Futaba, Namie, Katsurao, and Iitate). Regions colored in light gray correspond to municipalities designated as terminated/partial evacuation areas (Tamura, Minami-Soma, Kawamata, Hirono, and Kawauchi). Uncolored municipalities correspond to non-evacuation areas.

Total evacuation areas: Naraha, Tomioka, Okuma, Futaba, Namie, Katsurao, and Iitate

Terminated/partial evacuation areas: Tamura, Minami-Soma, Kawamata, Hirono, and Kawauchi

Non-evacuation areas: Other municipalities in Fukushima Prefecture

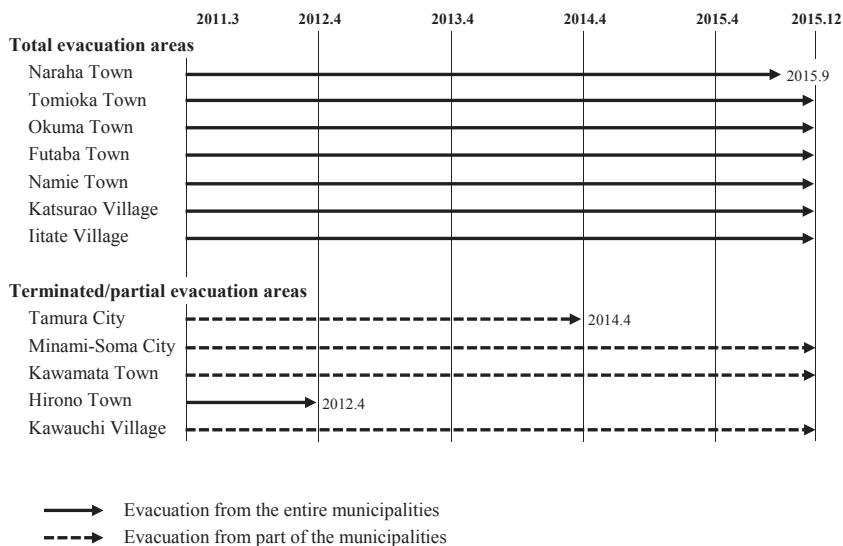


Figure 2. Transition of compulsory evacuation orders of residents from the entire or part of municipalities in total and terminated/partial evacuation areas

Note. In total evacuation areas, compulsory evacuation orders continued until December 2015 in entire municipalities, except Naraha Town (evacuation order lifted in September 2015 in Naraha). Compulsory evacuation orders were issued to parts of municipalities in terminated/partial evacuation areas or were lifted prior to 2015. The bold arrow corresponds to compulsory evacuation orders for entire municipalities, and the dotted arrow corresponds to compulsory evacuation orders to parts of municipalities.

Annual suicide rate = $\{\sum (\text{monthly number of suicides in each evacuation area or non-evacuation area}) / \sum (\text{Basic Resident Register population in each evacuation area or non-evacuation area})\} * 12$

Monthly suicide rates were analyzed by the following three methods. First, the exponential smoothing time series model was used to examine the trend of suicide rates post disaster and for future prediction (Zeng et al., 2016).

Second, period analysis was performed by dividing the 81-month study period into five segments (12 months in each period from March 2009 to February 2015, and 10 months in each period from April 2015 to December 2015), and suicide rates were compared with the national

Table 1. Basic information regarding the total and terminated/partial evacuation areas

Areas	Population as of March 11, 2011 ¹	Population as of January 1, 2015 ²
Evacuation areas	188,297	173,210
Total evacuation areas	50,669	46,568
Naraha Town	8,011	7,448
Tomioka Town	15,937	14,111
Okuma Town	11,505	10,849
Futaba Town	7,140	6,354
Katsurao Village	1,567	1,489
Iitate Village	6,509	6,317
Terminated/partial evacuation areas	137,628	126,642
Tamura City	41,662	39,484
Minami-Soma City	71,561	64,539
Kawamata Town	15,877	14,732
Hirono Town	5,490	5,148
Kawauchi Village	3,038	2,739
Non-evacuation areas	1,828,129 ³	1,773,092

Notes. ¹Fukushima prefectural government, Japan. ²Cabinet Office, Government of Japan. ³As of March 31, 2011. Cabinet Office, Government of Japan. Evacuation area = 12 municipalities designed as radiation hazard areas by Japanese government. Non-evacuation areas = Other municipalities in Fukushima Prefecture.

Table 2. Raw data on the number of suicides and rates in the evacuation and non-evacuation areas (81-month period, March 2009–December 2015)

	Number of suicides (per month)			Annualized rates (per month, per 100,000)		
	Median	Max.	Min.	Median	Max.	Min.
Men						
Evacuation areas	3	7	0	34.7	88.9	0.0
Total evacuation areas	1	4	0	33.4	138.1	0.0
Terminated/partial evacuation areas	2	7	0	35.8	135.0	0.0
Non-evacuation areas	24	46	11	33.0	62.0	15.2
National average	1.540	2.174	1.185	29.5	42.0	22.7
Women						
Evacuation areas	1	5	0	12.0	60.1	0.0
Total evacuation areas	0	2	0	0.0	70.7	0.0
Terminated/partial evacuation areas	1	4	0	17.1	72.8	0.0
Non-evacuation areas	9	23	3	11.9	29.4	3.9
National average	657	1,035	497	12.1	19.2	9.1

Notes. Evacuation area = 12 municipalities designed as radiation hazard areas by Japanese government. Non-evacuation areas = Other municipalities in Fukushima Prefecture.

average of the corresponding period using Poisson distribution. Third, suicide rates were analyzed by age categories using a 2-year simple moving average because the number of age-categorized suicide cases was small. In addition, we compared suicide rates between total evacuation areas and terminated/partial evacuation areas by period analysis and age-based analysis.

Results

Changes in Suicide Rates in Evacuation and Non-Evacuation Areas by the Exponential Smoothing Time Series Model

Changes in suicide rates in evacuation and non-evacuation areas were examined using the exponential smoothing

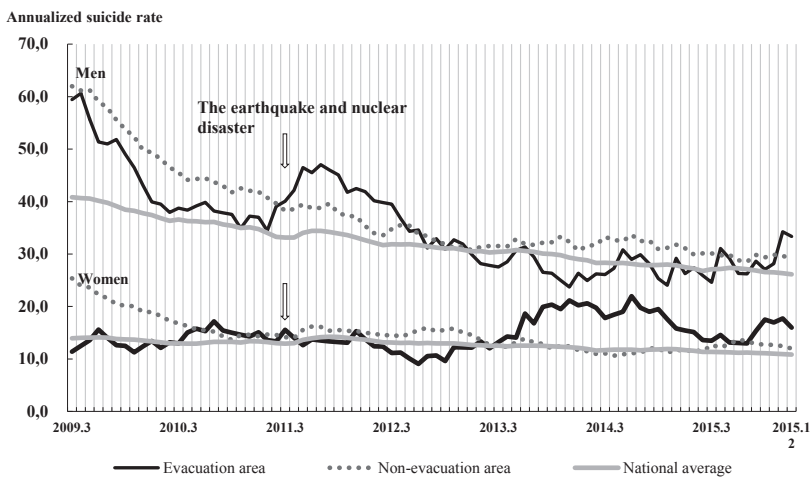


Figure 3. Changes in suicide rates in evacuation and non-evacuation areas by the exponential smoothing time series model

Notes. Changes in suicide rates (per 100,000 people) in the evacuation and non-evacuation areas. The solid and dotted lines show the transition of suicide rates in the evacuation areas and non-evacuation areas, respectively. The light gray line shows the transition of the national average. The arrows indicate the occurrence of the nuclear disaster following the Great East Japan Earthquake.

Annualized suicide rate: Monthly suicide number / population × 100,000 × 12

Evacuation areas: Tamura, Minami-Soma, Kawamata, Hirono, Naraha, Tomioka, Kawauchi, Okuma, Futaba, Namie, Katsurao, and Iitate

Non-evacuation areas: Other municipalities in Fukushima Prefecture

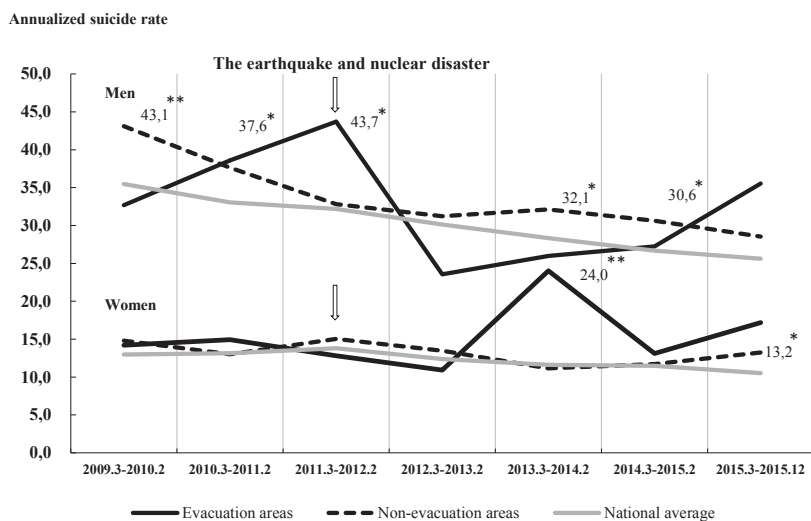


Figure 4A. Comparison of suicide rates in evacuation areas and non-evacuation areas with the national average

Notes. Suicide rates (per 100,000 people) in evacuation areas and non-evacuation areas are shown by postdisaster period. The bold line and dotted line show the transition of suicide rates in evacuation areas and non-evacuation areas, respectively. The arrows indicate the occurrence of the nuclear disaster following the Great East Japan Earthquake. Postdisaster suicide rates were compared with the national average using Poisson distribution.

* $p < .05$, ** $p < .01$, Poisson distribution test

Annualized suicide rate: Monthly suicide number / population × 100,000 × 12

Evacuation areas: Tamura, Minami-Soma, Kawamata, Hirono, Naraha, Tomioka, Kawauchi, Okuma, Futaba, Namie, Katsurao, and Iitate

Non-evacuation areas: Other municipalities in Fukushima Prefecture

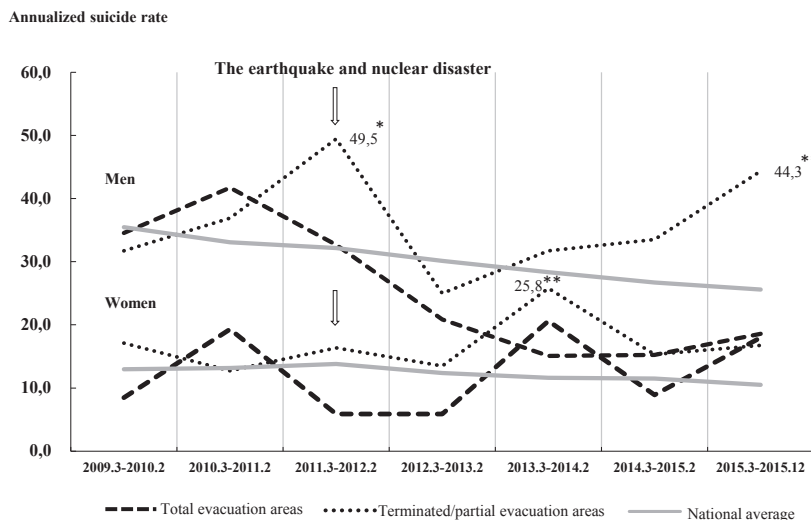


Figure 4B. Comparison of suicide rates in total evacuation areas and terminated/partial evacuation areas with the national average

Notes. Suicide rates (per 100,000 people) in total evacuation areas and terminated/partial evacuation areas are shown by postdisaster period. The bold dotted line and thin dotted line show the transition of suicide rates in total evacuation areas and terminated/partial evacuation areas, respectively. The arrows indicate the occurrence of the nuclear disaster following the Great East Japan Earthquake. Postdisaster suicide rates were compared with the national average using Poisson distribution.

* $p < .05$, ** $p < .01$, Poisson distribution test

Annualized suicide rate: Monthly suicide number / population × 100,000 × 12

Total evacuation areas: Naraha, Tomioka, Okuma, Futaba, Namie, Katsurao, and Iitate

Terminated/partial evacuation areas: Tamura, Minami-Soma, Kawamata, Hirono, and Kawauchi

Table 3. Suicide rates by period analysis compared to national averages using a Poisson distribution

Sex	Area	Suicide rate by each period (per 100,000)						
		2009.3–2010.2	2010.3–2011.2	2011.3–2012.2	2012.3–2013.2	2013.3–2014.2	2014.3–2015.2	2015.3–2015.12
Men	Evacuation areas	32.7 ($p = .36$)	38.6 ($p = .18$)	43.7* ($p = .03$)	23.6 ($p = .14$)	26.0 ($p = .38$)	27.2 ($p = .48$)	35.6 ($p = .05$)
	Total evacuation areas	34.5 ($p = .54$)	41.7 ($p = .22$)	32.7 ($p = .52$)	20.8 ($p = .21$)	15.1 ($p = .09$)	15.2 ($p = .13$)	18.6 ($p = .28$)
	Terminated/partial evacuation areas	31.7 ($p = .35$)	36.9 ($p = .32$)	49.5* ($p = .01$)	25.0 ($p = .27$)	31.7 ($p = .34$)	33.5 ($p = .18$)	44.3** ($p < .01$)
	Non-evacuation areas	43.1* ($p < .01$)	37.6* ($p = .01$)	32.8 ($p = .37$)	31.2 ($p = .28$)	32.1* ($p = .02$)	30.6* ($p = .02$)	28.5 ($p = .05$)
	National average	35.5	33.1	32.2	30.1	28.4	26.7	25.6
Women	Evacuation areas	14.2 ($p = .40$)	14.9 ($p = .34$)	12.8 ($p = .46$)	10.9 ($p = .41$)	24.0* ($p < .01$)	13.1 ($p = .35$)	17.2 ($p = .06$)
	Total evacuation areas	8.5 ($p = .33$)	19.3 ($p = .21$)	5.9 ($p = .15$)	5.9 ($p = .21$)	20.6 ($p = .10$)	8.9 ($p = .46$)	18.0 ($p = .14$)
	Terminated/partial evacuation areas	17.1 ($p = .21$)	12.7 ($p = .55$)	16.3 ($p = .33$)	13.5 ($p = .44$)	25.8** ($p < .01$)	15.3 ($p = .22$)	16.8 ($p = .15$)
	Non-evacuation areas	18.8 ($p = .07$)	11.3 ($p = .47$)	17.4 ($p = .17$)	11.2 ($p = .18$)	10.8 ($p = .36$)	11.3 ($p = .43$)	16.2* ($p = .01$)
	National average	13.0	13.2	13.8	12.4	11.6	11.5	10.5

Notes. Evacuation areas = All municipalities in the whole & the other evacuation areas.
 Total evacuation areas = Naraha, Tomioka, Okuma, Futaba, Namie, Katsurao, and Iitate.
 Terminated/partial evacuation areas = Tamura, Minami-Soma, Kawamata, Hirono, and Kawauchi.
 Non-evacuation areas = Other municipalities in Fukushima Prefecture.
 * $p < .05$; ** $p < .01$

Table 4. Suicide mortality rate by age group in evacuation area

Area	Period	Suicide mortality rate (per 100,000)								
		Men				Women				
		≤ 29	30–49	50–69	≥ 70	≤ 29	30–49	50–69	≥ 70	
Whole evacuation area	Pre-	2009.3–2011.2	9.2	34.9	65.8	51.9	0.0	0.0	25.8	33.9
		2010.3–2012.2	14.0	29.9	52.0	68.0	0.0	0.0	26.0	24.5
	Post-	2011.3–2013.2	19.8	12.5	24.0	68.8	0.0	0.0	15.8	6.3
		2012.3–2014.2	15.2	12.6	14.4	39.0	5.4	0.0	21.0	25.2
		2013.3–2015.2	10.4	6.4	19.3	28.9	5.5	0.0	15.8	37.6
		2014.3–2015.12	11.8	0.0	26.3	43.9	6.7	0.0	11.7	34.8
Terminated/partial evacuation areas	Pre-	2009.3–2011.2	12.8	44.6	51.7	28.2	2.7	13.4	20.5	25.4
		2010.3–2012.2	18.4	48.6	59.1	48.2	2.8	13.9	10.3	31.1
	Post-	2011.3–2013.2	16.7	43.7	44.8	48.2	0.0	7.3	20.9	28.5
		2012.3–2014.2	14.4	27.3	34.9	39.3	3.1	7.4	23.6	39.8
		2013.3–2015.2	23.8	27.6	32.5	52.1	12.8	7.5	15.9	42.4
		2014.3–2015.12	23.2	50.6	33.0	61.9	9.8	17.6	20.9	15.2

Notes. Evacuation areas = All municipalities in the whole & the other evacuation areas.
 Total evacuation areas = Naraha, Tomioka, Okuma, Futaba, Namie, Katsurao, and Iitate.
 Terminated/Partial evacuation areas = Tamura, Minami-Soma, Kawamata, Hirono, and Kawauchi.
 Non-evacuation areas = Other municipalities in Fukushima Prefecture.

time series model (Figure 3). In evacuation areas, male suicide rates increased immediately after the disaster and then declined over the course of approximately 2.5 years postdisaster. In addition, while suicide rates were higher in evacuation areas compared with those of non-evacuation areas and the national average for approximately 1.5 years postdisaster, they then decreased to levels equivalent to non-evacuation areas and the national average. During the approximately 1.5–4 years after the disaster, suicide rates in evacuation areas remained lower than those of non-evacuation areas, but exceeded the rates in non-evacuation areas at 4.5 years postdisaster and showed an increasing trend thereafter. Female suicide rates in evacuation areas declined slightly during the initial period of approximately 1.5 years postdisaster, but then increased to exceed those of non-evacuation areas as well as the national average.

Comparison of Suicide Rates in Evacuation and Non-Evacuation Areas With the National Average Using Poisson Distribution

A comparison of predisaster male suicide rates in evacuation areas with the national average using Poisson distribution showed no significant difference. During the first 12-month postdisaster period (March 2011 to February 2012), male suicide rates in evacuation areas were significantly higher than the national average ($p = .03$); however, they then decreased to below the national average and remained low during the second and third 12-month periods (March 2012 to February 2014). Subsequently, after the fourth 12-month period, male suicide rates in evacuation areas were higher again compared with the national average. In non-evacuation areas, male suicide rates were significantly higher than the national average predisaster but subsequently reached the national average during the first and second 12-month postdisaster periods. However, suicide rates increased significantly thereafter, exceeding the national average during the postdisaster period. During the first and second postdisaster periods, female suicide rates in evacuation areas did not show significant changes as compared with the national average, although there were steep, significant increases during the third 12-month postdisaster period (from March 2013 to February 2014; $p < .01$).

In the present study, male suicide rates in non-evacuation areas only showed a decreasing trend after the disaster relative to the national average. However, during the third and fourth 12-month postdisaster periods (March 2013 to February 2015), male suicide rates increased significantly compared with the national average. Moreover, female suicide rates increased during the first postdisaster period (March 2011 to February 2012), but then decreased to reach the

national average. However, significant increases were observed during the fifth postdisaster period (March 2015 to December 2015) compared with the national average (Table 3 and Figure 4A).

Comparison of Suicide Rates in Total Evacuation Areas and Terminated/Partial Evacuation Areas With the National Average Using Poisson Distribution

Compared with the national average, male suicide rates in total evacuation areas were lower after the second postdisaster period (March 2012 to February 2013) and remained low thereafter. On the other hand, suicide rates in terminated/partial evacuation areas were consistently above the national average, except during the second postdisaster period. In particular, suicide rates in terminated/partial evacuation areas were significantly higher than the national average during the first and fifth postdisaster periods. Moreover, female suicide rates in total evacuation areas and terminated/partial evacuation areas were comparable to male suicide rates in total evacuation areas. Postdisaster suicide rates in total evacuation areas were consistently lower compared with terminated/partial evacuation areas (Table 3 and Figure 4B).

Analysis of Suicide Rates by Age Categories in Evacuation Areas (Total and Terminated/Partial Evacuation Areas) and Non-Evacuation Areas

Male suicide rates in evacuation areas decreased greatly after the first postdisaster period (March 2011 to February 2013) for those aged 30–49 and 50–69 years, and increased for those aged ≤ 29 years and ≥ 70 years. During the subsequent postdisaster periods, suicide rates among those aged 50–69 years in evacuation areas remained lower, while suicide rates among those aged ≤ 29 years and ≥ 70 years remained higher than predisaster rates (March 2009 to February 2011). During the first postdisaster period, female suicide rates in the evacuation areas were similar to predisaster rates in all age categories. However, during the third postdisaster period (March 2013 to February 2015), suicide rates among those aged ≤ 29 years and ≥ 70 years increased (Table 4).

Discussion

Our findings revealed an immediate increase in suicide rates after the Fukushima nuclear disaster only among men in terminated/partial evacuation areas. After subsequently decreasing temporarily once, delayed increases were observed in suicide rates in evacuation areas, with rates differing by gender, age, and area. In a previous study on the Chernobyl nuclear disaster, a long-term increase in suicide rates among clean-up workers was reported (Bromet & Havenaar, 2007). Moreover, we observed similar changes in suicide rates as reported by other previous studies concerning the 1995 Great Hanshin-Awaji Earthquake, as well as the Great East Japan Earthquake and subsequent tsunami disaster. Specifically, suicide rates decreased immediately after the disaster, with a subsequent increase over the course of roughly 1.5–2 years (Nishio et al., 2009; Ohto, Maeda, Yabe, Yasumura, & Bromet, 2015; Orui et al., 2015). While the delayed increase in suicide rates is a consistent finding in this and other studies, we also observed gender differences in the present study. Specifically, female suicide rates increased after 1.5 years during the postdisaster period, whereas male suicide rates increased immediately following the disaster, then declined below the national average, and subsequently increased after 2.5 years after the disaster.

We found several differences in postdisaster suicide rates by age category and gender. Suicide rates among male elderly individuals (≥ 70 years) in evacuation areas increased immediately following the disaster, whereas female suicide rates increased with a delay. A number of previous studies examined factors related to suicide ideation and suicide attempts among the elderly, and found depression and social problems (e.g., thwarted belongingness, perceived burdensomeness, or hopelessness to live), chronic interpersonal difficulties, and family conflicts to be risk factors (Shinfuku, 2002; Szanto et al., 2012; Van Orden et al., 2010; Van Orden et al., 2015). Drastic life changes accompanying mandatory evacuation could cause psychological disorders and social problems, possibly leading to increased suicide rates among the elderly. With respect to increased suicide rates among the youth (≤ 29 years), increased hopelessness, mental disorders, and negative life events have been shown to be important factors contributing to suicide in this population (Zhang, Li, Tu, Xiao, & Jia, 2011). Moreover, losing their means of livelihood after the disaster may have exacerbated their grief (Li, Chow, Shi, & Chan, 2015), which could be a risk factor for suicidality (Latham & Prigerson, 2004).

We found a steep decrease in suicide rates among middle-aged male adults, especially those aged 30–69 years in evacuation areas, but not in females. Suicide rates among

men are reportedly associated with economic circumstances, such as increased unemployment and bankruptcy (Aihara & Iki, 2003; Yamasaki et al., 2008). One study regarding the 2008 global economic recession and suicide reported that men aged 45–64 years were most affected in European and North and South American countries (Chang, Stuckler, Yip, & Gunnell, 2013). Therefore, the decline in suicide rates in this age category may have contributed to the declining male suicide rates in the second postdisaster period (March 2012 to February 2013). However, there is often a decrease in nonfatal suicidal behavior in the immediate aftermath of a disaster, which is referred to as the *honeymoon period* (Madianos & Evi, 2010). Another study reported that the feeling of pulling together during a natural disaster can reduce interpersonal risk factors associated with the desire for suicide (Gordon, Bresin, Dombeck, Routledge, & Wonderlich, 2011). Following the Great East Japan Earthquake, more intensive mental health-care services were provided to evacuees who lived in evacuation areas. Although specific reasons for trends in suicide rates were not determined in the present study, the initial decrease in postdisaster suicide rates might be attributed not only to economic factors, but also to the aforementioned phenomena and intensive mental health-care activities.

In the present study, changes in suicide rates differed between total evacuation areas and terminated/partial evacuation areas. However, male suicide rates in total evacuation areas decreased steeply after the disaster as compared with terminated/partial evacuation areas. In particular, the decrease in suicide rates among those aged 30–69 years was prominent in total evacuation areas.

One possible explanation is that residents in evacuation areas (i.e., those who lived near the nuclear power plant) were financially compensated for nuclear damages, including mental damage caused by evacuation, loss of income, and damage to agriculture, forestry, fishery, and food industries after the nuclear disaster (TEPCO, Dec 15, 2017). According to Fukushima prefectural government reports, the rates of households receiving public assistance decreased steeply after the disaster in Soso county, which includes all seven municipalities designated as total evacuation areas (from 0.37% in 2011 to 0.07% in 2014). On the other hand, the rates of households receiving public assistance did not decrease after the disaster in Tamura City and Minami-Soma City, whose residents account for 82% of the population in terminated/partial evacuation areas (Tamura City, 0.59% in 2011 to 0.54% in 2014; Minami-Soma City, 0.35% in 2011 to 0.32% in 2014). While residents of total evacuation areas could all receive financial compensation, only some residents in terminated/partial evacuation areas (i.e., those who lived in areas subject to ongoing evacuation) were pro-

vided with such aid. Provision of financial compensation for evacuees will end when radiation hazard regulations are removed, and consequently, economic circumstances may worsen relative to the current state. This could possibly lead to increased suicide rates in evacuation areas, especially in total evacuation areas. Moreover, long-term evacuation orders are unique to nuclear disasters, as compared with other natural disasters. In fact, residents of areas near the nuclear plant remain under evacuation from their homes, with almost 80,000 people unable to return to their homes (as of February 2017). These individuals may face difficult choices regarding whether or not to return to their hometown when radiation hazard regulations are removed. Numerous conflicts may arise not only from radiation concerns, but also due to the lack of employment opportunities, educational services, medical/nursing care services, and commercial facilities. Given the increase in male suicide rates in terminated/partial evacuation areas during the recent postdisaster period, careful observation will be needed, and active postdisaster mental health services should be provided continuously to prevent a future rise in suicide rates.

In addition, based on male suicide rates in non-evacuation areas, it might indicate a temporary decrease, subsequently increasing significantly compared with the national average. Therefore, careful observation and rigorous implementation of suicide prevention measures will be required in non-evacuation areas as well.

Limitations

This study has several limitations. First, every victim of the present disaster had to relocate to areas outside the evacuation zone; therefore, some evacuees might have changed their certificate of residence information, possibly resulting in an underestimation of suicide rates. Although 83.3% of victims in evacuation areas were estimated to have not changed their certificate of residence information, some may have updated their certificate to non-evacuation areas, which could lead to increased suicide rates in non-evacuation areas. This rate was calculated as follows:

$$\frac{[(\text{Population as of March 11, 2011}) - \sum_{(2011-2015)} (\text{Number of those who moved in/out}) - \sum_{(2011-2015)} (\text{Number of deaths}) - \sum_{(2011-2015)} (\text{Number of births})]}{[(\text{Population as of March 11, 2011}) - \sum_{(2011-2015)} (\text{Number of deaths}) - \sum_{(2011-2015)} (\text{Number of births})]}$$

Second, data used in this study were limited with respect to terminated/partial evacuation areas. While evacuation orders were terminated in Hirono Town (as of April 2012) and Tamura City (as of April 2014), they remain effective

in some parts of Minami-Soma City, Kawamata Town, and Kawauchi Village. Therefore, situations regarding evacuation orders varied in terminated/partial evacuation areas during the observation period. In addition, suicide data included deaths by suicide in non-evacuation areas of municipalities designated as partial evacuation areas, since the evacuation order designated only parts of Tamura City, Minami-Soma, City, Kawamata Town, and Kawauchi Village. Therefore, the use of suicide data (by municipal unit) from vital statistics might be an additional limitation.

Third, the national suicide rates of males tended to decline consistently during the observation period. Therefore, the immediate decrease in suicide rates after the disaster may have reflected the nationwide decline in suicide rates.

Finally, the number of suicides among females and the female population in the subject area, especially in total evacuation areas, was small. The number of suicide cases per month was 2 at most (and 7 per year) during the observation period among the female population of approximately 35,000. This could be the reason why no significant difference was observed in female suicide rates between total evacuation areas and the national average.

Conclusion

Despite these limitations, the strength of the present study is that we used data from vital statistics (e.g., certificate of residence information and age), which allowed us to track residents who had relocated to non-evacuation areas after the disaster. Our results confirmed the initial increase in male suicide rates in evacuation areas. Moreover, a delayed increase in suicide rates was observed in both genders, highlighting the importance of providing intensive, long-term mental health-care services following a disaster, given that suicide rates might eventually increase after major natural disasters (Kölves, Kölves, & De Leo, 2013; Matubayashi, Sawada, & Ueda, 2013). Interestingly, our findings also suggested the possibility that suicide rates will increase after termination of radiation hazard regulations. These regulations have already been terminated in the entire area of Kawamata Town and Kawauchi Village, which were designated as partial evacuation areas in the present study, and in the majority of areas in Minami-Soma City, Tomioka Town, Katsurao Village, and Iitate Village. Given the recent increase in suicide rates in these areas, careful observation of suicide trends will be needed in evacuation areas and non-evacuation areas, while providing active and continuous postdisaster mental health services to prevent future increases in suicide rates. We hope our findings will provide helpful insights to disaster mental health service providers.

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