

Associations Between the 2011 Great East Japan Earthquake and Tsunami and the Sleep and Mental Health of Japanese People: A 3-Wave Repeated Survey

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Purpose: Large-scale natural disasters have an enormous physical and mental impact, immediately after they occur, on people living near the central disaster areas. It is known that, in the early stages, a seismic disaster triggers high rates of symptoms for insomnia, depression, and anxiety. However, little information is available about their medium- to long-term clinical outcomes. In this study, we conducted a repeated cross-sectional nationwide questionnaire survey to clarify changes in the prevalence of insomnia and its background factors after the Great East Japan Earthquake, a huge earthquake with a moment magnitude of 9.0 that occurred on March 11, 2011.

Methods: We conducted a repeated cross-sectional survey in November 2009 (pre-earthquake, 1224 participants), July 2011 (4 months post-earthquake, 1259 participants), and August 2012 (18 months post-earthquake, 1289 participants) using stratified random sampling from 157 Japanese sites.

Results: Compared to 2009, the prevalence of insomnia statistically increased nationwide immediately post-disaster (11.7% vs 21.2%; $p < 0.001$) but significantly decreased in 2012 compared to immediately after the earthquake (10.6% vs 21.2%; $p < 0.001$). In 2011, insomnia was most frequent in the central disaster area. Multivariable logistic regression models demonstrated the association between the following factors and increased risk of insomnia: being a woman (odds ratio [OR] 1.48, 95% confidence interval [CI]: 1.00–2.19), being employed in 2009 (OR 1.74, 95% CI: 1.15–2.62), and being of younger age group (20–64 years) in 2011 (OR 1.64, 95% CI: 1.12–2.42) and 2012 (OR 2.50 95% CI: 1.47–4.23). Post-earthquake, the prevalence of insomnia symptoms in men increased, while the gender difference decreased and was no longer statistically significant. Additionally, insomnia was associated with psychological distress (scores ≥ 5 on the Kessler Psychological Distress Scale) in 2011 and 2012.

Conclusion: This study demonstrated that the prevalence of insomnia was significantly higher after the earthquake. Moreover, individuals with insomnia were more likely to experience psychological distress after the earthquake that continued until 2012.

Keywords: disaster, earthquakes, insomnia, psychological stress

Introduction

Japan experienced a huge earthquake with a moment magnitude of 9.0 at 14:46 on March 11, 2011. Together with the subsequent tsunami, it resulted in a major catastrophe that caused the death and disappearance of nearly 19,000 residents. The Fukushima Daiichi Nuclear Power Plant was directly hit, which caused a station blackout that, in

turn, resulted in a Level 7 nuclear power accident. Consequently, anxiety about radiation exposure and power outages persisted even long after the disaster.

One to two months after the seismic disaster, various mental health surveys revealed that approximately 60% of the local residents experienced some form of insomnia.^{1–4} In normal circumstances, 20–30% of adults experience insomnia symptoms such as difficulty initiating sleep (DIS), nocturnal awakening, early arousal, or deteriorated sleep quality.⁵ However, during large-scale disasters, the frequency of these symptoms increases sharply two- or three-fold, at least temporarily.

Acute forms of insomnia (short-term insomnia) triggered by seismic disaster-related stress appear to develop into chronic sleep disorders. However, the actual process is unclear. The Diagnostic and Statistical Manual of Mental Disorders, 5th edition, and the International Classification of Sleep Disorders, 3rd edition, define insomnia as the presence of insomnia symptoms that persist for three months or longer, along with various functional disorders such as daytime drowsiness, malaise and depression, decline in psychomotor function, and gastrointestinal symptoms.^{6,7} In normal circumstances, the incidence of insomnia is assumed to be more than 6% in the general population.^{5,8–12}

Chronic sleep disorders reduce the quality of life¹³ and cause personal and socioeconomic losses such as increases in long-term absence from work, reductions in work efficiency, loss of productivity, greater frequency of industrial accidents, and higher medical expenses.^{1–4,14–17} Insomnia also often coexists with mental illnesses such as mood and anxiety disorders.^{18–20} Further, chronic insomnia is a prodrome of the depression phase²¹ and a risk factor for the onset and recurrence of depression. Thus, the risk of depression among individuals with insomnia is two to three times higher than in those without insomnia.^{22,23}

To investigate changes in the prevalence of insomnia and its background factors after the Great East Japan Earthquake, we had conducted a repeated cross-sectional nationwide questionnaire survey in Japan, 4 and 18 months after the earthquake, and compared the results with data from surveys conducted before the earthquake.

Methods

Sample and Methods

Participant Selection and Method of Investigation

As part of a research project funded by the Ministry of Health, Labour and Welfare, we first conducted two cross-sectional

surveys—one in July 2011 (4 months after the earthquake) and another in September 2012 (18 months after the earthquake)—each over a one-month period to examine Japanese residents' sleep status. We used the results of another cross-sectional survey conducted in November 2009, 16 months before the earthquake, as the control data to determine participants' working status, rest, sleep habits, and insomnia symptoms. The three cross-sectional surveys employed the same investigation method.

To ensure representativeness, we used stratified three-stage randomization to select 4000 Japanese residents over 20 years of age. We divided the nation's cities, towns, and villages into 12 blocks (Hokkaido, Tohoku, Kanto, Keihin, Koshinetsu, Hokuriku, Tokai, Kinki, Hanshin, Chugoku, Shikoku, and Kyushu) based on prefecture or city, and 36 groups stratified by the size of the city or county in each block (20 largest cities, other cities, and county areas). Additionally, 157 sites were selected using the basic unit wards of the survey area established at the time of the 2005 census and adjusted so that the number of individuals to be sampled per survey area was 25. Ultimately, we extracted 157 sites. To select households, we used an electronic residential map database (OA-TOWN II, Zenrin).

Among the 157 sites, we randomly selected one target household from every three households. Within each target household, individuals over 20 years old whose birthdates were closest to the survey implementation month were designated as potential participants. After participant identification, the investigators visited 4000 households during the one-month survey period. The number of eligible participants in 2009, 2011, and 2012 was 2206, 2254, and 2238, respectively. We obtained informed consent from 1224 people in 2009 (response rate=55.5%), 1259 in 2011 (55.9%), and 1289 in 2012 (57.6%). After excluding inadequate or incomplete responses, we analyzed the data of 1223, 1254, and 1281 individuals in 2009, 2011, and 2012, respectively. The survey was conducted by investigators trained in interviewing techniques. The Akita University Graduate School of Medicine Ethics Committee approved this study (approval no. 2522). All participants provided informed consent to take part in this study, in accordance with the Declaration of Helsinki.

Classification of Areas by Disaster Impact

We used existing data to select the following three areas from the prefectures where the participants resided (Figure 1):

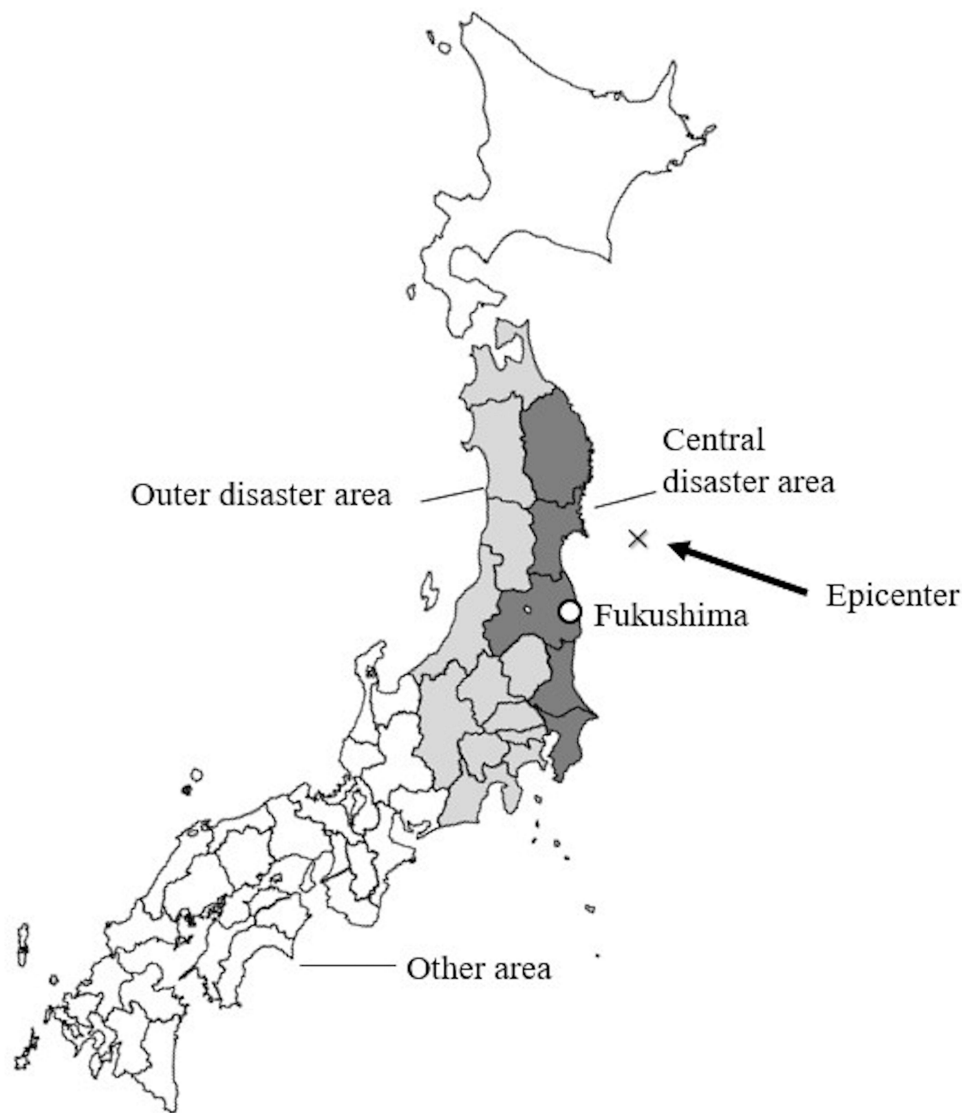


Figure 1 Map of the central, outer, and other disaster areas.

Notes: Dark gray areas; Five prefectures along the Pacific Coast in Eastern Japan (Iwate, Miyagi, Fukushima, Ibaraki, Chiba: “central disaster area”). These were close to the epicenter, with a maximum seismic impact of more than 6, and suffered damage because of the inundation of the tsunami. Gray areas; Twelve prefectures that experienced a maximum seismic impact over 6 but were unaffected by the tsunami or experienced a maximum seismic impact of 5–6 (Aomori, Akita, Yamagata, Niigata, Gunma, Tochigi, Saitama, Tokyo, Kanagawa, Yamanashi, Nagano, and Shizuoka: “outer disaster area”). Uncolored area; Areas other than the above that suffered relatively little damage (“other areas”).

1. Five prefectures along the Pacific Coast in Eastern Japan (Iwate, Miyagi, Fukushima, Ibaraki, Chiba: “central disaster area”). These were close to the epicenter, with a maximum seismic impact of more than 6, and suffered damage because of the inundation of the tsunami.
2. Twelve prefectures that experienced a maximum seismic impact over 6 but were unaffected by the tsunami or experienced a maximum seismic impact of 5–6 (Aomori, Akita, Yamagata, Niigata, Gunma, Tochigi, Saitama, Tokyo, Kanagawa, Yamanashi, Nagano, and Shizuoka: “outer disaster area”).
3. Areas other than the above that suffered relatively little damage (“other areas”).

Survey Items

Basic Attributes

For the 3-wave repeated survey, we collected data on the residents’ gender, age, and prefecture of residence. Under Japan’s current employment system, ages 60–65 correspond with the average mandatory retirement period. Therefore, we established two age groups: (a) the younger age group (aged 20–64) and (b) the older age group (aged 65 and above).

Evaluation of Insomnia Symptoms

In the 3-wave repeated survey, we posed the following five questions regarding insomnia symptoms and the presence or absence of related functional disorders, as well as their frequency over the past month:

Q1. Have you had any difficulties falling asleep at night? (difficulty initiating sleep [DIS])

Q2. Have you woken up in the middle of the night and had difficulty getting back to sleep? (difficulty maintaining sleep [DMS])

Q3. Have you woken up early in the morning or at dawn and had difficulty getting back to sleep? (early morning awakening [EMA])

Q4. How do you evaluate your overall sleep quality? (deteriorated sleep quality [DSQ])

Q5. Have you experienced impairments in your life and actions/behaviors during the day because of not getting enough sleep as described above? (eg, fatigue, work performance, concentration, memory, mood, drowsiness, and functional disorders caused by insomnia)

For Q1–3 and Q5, participants had to choose the most applicable response from five options (“Always,” “Often,” “Sometimes,” “Rarely,” and “Never”). For Q4, they had to choose from four options (“Very good,” “Good,” “Bad,” and “Very bad”).

Definition of Insomnia

We defined insomnia according to the general criteria in the International Classification of Sleep Disorders: Diagnostic and Coding Manual, 2nd edition.^{5,24} Participants who chose “Sometimes,” “Often,” or “Always” for Q1–3; “Bad” or “Very bad” for Q4; and “Sometimes,” “Often,” or “Always” for Q5 were considered to have insomnia.

Evaluation of Post-Earthquake Mental Health

In the 2011 and 2012 surveys, we used the six-item Kessler Psychological Distress Scale (K6) to evaluate mental health after the earthquake. The K6 was developed to identify depression and anxiety disorders²⁵ and has been standardized for use with Japanese samples.²⁶ Scores range from 0 to 24 points, and higher scores indicate higher distress severity. A cutoff of 5 was used to identify cases of psychological distress.^{25,27}

Statistical Analysis

The prevalence of insomnia, daytime dysfunction, and any insomnia symptoms between 2009 and 2011 and between

2009 and 2012 was compared with 95% confidence intervals (CIs) calculated using the Wilson method; *p*-values were estimated using the two-proportions *z*-test. Similarly, gender, age, and residential area were compared between individuals with and without insomnia in 2009, 2011, and 2012. The chi-square test was used to test the statistical differences between categorical variables, and the *t*-test or Mann–Whitney *U*-test were used for continuous variables. To identify the risk factors for insomnia in 2009, 2011, and 2012, we performed a multivariable logistic regression analysis with simultaneous inclusion of gender, age, education, job groups, and disaster area, and calculated the adjusted odds ratios (ORs) with 95% CIs.

To analyze post-earthquake mental health status in 2011 and 2012, we first compared the median of continuous K6 scores between individuals with and without insomnia using the Mann–Whitney *U*-test. Then, we explored the relationship between insomnia and the following two K6 categories using the chi-square test: “normal” (<5 points) and “psychological stress-equivalent group” (≥5 points).

All analyses were two-tailed and performed using SPSS for Windows version 25.0 (IBM Corp., Armonk, NY, USA). The statistical significance was set at *p*<0.05.

Results

Participants' Demographic Characteristics

The gender ratios were 78.5, 84.1, and 80.9 men per 100 women in 2009, 2011, and 2012, respectively, depicting similar ratios across the years. The average age was also similar: 51.0 years (range: 20–98) in 2009, 51.9 years (range: 20–93) in 2011, and 52.8 years (range: 20–93) in 2012; however, the statistical difference was clearly observed between 2009 and 2012 (*p*=0.01). For educational attainment, we observed a slightly higher proportion of junior college and university graduates in 2012 compared to 2009. The proportion of participants living in the central disaster area did not significantly vary across the years, with 11.8% in 2009, 12.1% in 2011, and 10.6% in 2012 (Table 1).

Prevalence of Insomnia Before and After the Earthquake

Table 2 shows the prevalence of insomnia symptoms, daytime dysfunction, and insomnia in 2009, 2011, and 2012.

Table I Characteristics of Survey Sample Groups

	2009	2011	2012	vs 2011 ^a	vs 2012 ^a
	n = 1223	n = 1254	n = 1281	<i>p</i> ^b	
Gender					
Men	538 (44.0)	573 (45.7)	573 (44.7)	0.39	0.71
Women	685 (56.0)	681 (54.3)	708 (55.3)		
Age					
Mean	51 (17.16)	51.9 (17.2)	52.8 (17.7)	0.20	0.01
Age group					
20–64	909 (74.3)	894 (71.3)	889 (69.4)	0.09	0.01
≥65	314 (25.7)	360 (28.7)	392 (30.6)		
Education					
Below high school	158 (12.9)	155 (12.3)	140 (10.9)	0.31	0.02
High school	661 (54.0)	648 (51.7)	651 (50.8)		
Junior college degree or higher	404 (33.0)	451 (36.0)	490 (38.3)		
Job group					
Agriculture/forestry/fishery	15 (1.2)	27 (2.1)	12 (0.9)	0.23	0.32
Commerce/service industry	125 (10.2)	144 (11.5)	151 (11.8)		
Office job	199 (16.3)	225 (17.9)	221 (17.3)		
Labor	287 (23.5)	258 (20.5)	266 (20.8)		
Freelance/management	36 (2.9)	27 (2.1)	25 (2.0)		
Housewife	328 (26.8)	336 (26.8)	357 (27.9)		
Student	29 (2.4)	25 (2.0)	24 (1.9)		
Other/unemployed	204 (16.7)	212 (16.9)	225 (17.6)		
Disaster area					
Central	144 (11.8)	152 (12.1)	136 (10.6)	0.59	0.13
Outer	419 (34.3)	451 (36.0)	488 (38.1)		
Other	660 (54.0)	651 (51.9)	657 (51.3)		

Notes: ^aThe *p*-values of the chi-square test indicate the comparison of each item between 2009 and 2011, and between 2009 and 2012. ^bThe reported *p*-values are based on the χ^2 test for categorical variables and the independent *t*-test for continuous variables.

In 2009, women had a higher prevalence of insomnia, daytime dysfunction, and insomnia symptoms.

The prevalence of insomnia 4 months after the earthquake (2011) was 21.2% (95% CI: 20–23), which was statistically higher than before the disaster (11.7%, 95% CI: 10.3–13.4). The increased prevalence across all participants, genders, age groups, and areas was found to be decreased in 2012. Regarding gender, in 2011, the prevalence of insomnia was 19.0% in men and 23.1% in women. The prevalence of insomnia increased in both genders, but the increase was larger in men (from 8.8%, 95% CI: 7.1–11.1 in 2009 to 19.0%, 95% CI: 16.4–21.8 in 2011) than in women (from 14.1%, 95% CI: 12.0–16.3 in 2009 to 23.1%, 95% CI: 20.3–25.7 in 2011), and the statistically significant difference between men and women that was observed before the earthquake disappeared. Both younger and older age groups suffered from insomnia more in 2011 than in 2009. For the younger age

group, the prevalence of insomnia was significantly higher than among those aged 65 or older, both in 2011 (16.9% vs 22.9%; *p*=0.02) and 2012 (6.9% vs 12.4%; *p*<0.01).

Across all three areas, the prevalence of insomnia increased compared to that during the pre-disaster period. In particular, the prevalence of insomnia in 2011 was found to be most pronounced in the central disaster area (from 9.7%, 95% CI: 6.9–15.3 in 2009 to 25.7%, 95% CI: 20.3–31.9 in 2011). Furthermore, insomnia was also prevalent in outer disaster areas (from 12.6%, 95% CI: 10.2–15.6 in 2009 to 21.7%, 95% CI: 18.6–24.9 in 2011) as well as in other areas (from 11.6%, 95% CI: 9.6–13.7 in 2009 to 19.8%, 95% CI: 17.3–22.4 in 2011) throughout Japan; however, there was no statistical difference between areas in the same year.

The prevalence of daytime dysfunction of genders across the years was similar to that of insomnia. The prevalence of insomnia symptoms was statistically higher among women in 2009 and 2011. In terms of daytime dysfunction, there was

Table 2 Prevalence of Insomnia According to Gender, Age, and Disaster Area in 2009–2012

Insomnia						
	2009		2011		2012	
	n (%)	95% CI	n (%)	95% CI	n (%)	95% CI
All	143 (11.7)	10.3–13.4	266 (21.2) ^x	20–23.1	136 (10.6)	9.2–12.0
Gender						
Men	47 (8.8)	7.1–11.1	109 (19.0) ^x	16.4–21.8	57 (9.9)	8.0–12.1
Women	96 (14.1) ^a	12.0–16.3	157 (23.1) ^x	20.3–25.7	79 (11.2)	9.3–13.2
Age group						
20–64	104 (11.4)	9.9–16.1	205 (22.9) ^{bx}	20.6–25.2	110 (12.4) ^b	10.7–14.3
≥65	39 (12.4)	9.8–13.3	61 (16.9) ^x	13.9–20.3	26 (6.6) ^x	4.7–8.9
Education						
Less than high school	24 (15.2)	11.1–20.5	34 (21.9)	17.0–27.9	14 (10.0)	6.5–15.0
High school	70 (10.6)	8.8–12.7	129 (19.9) ^x	17.5–22.6	66 (10.1)	8.4–12.3
Junior college or higher	49 (12.1)	9.7–15.1	103 (22.8) ^x	19.8–26.3	56 (11.4)	9.3–14.0
Job groups						
Unemployed	84 (15.0) ^d	12.7–17.6	123 (21.5) ^x	18.8–24.4	64 (10.6)	8.7–12.8
Employed	59 (8.9)	7.2–10.9	143 (21.0) ^x	18.6–23.7	72 (10.7)	8.9–12.8
Disaster area						
Central	14 (9.7)	6.9–15.3	39 (25.7) ^x	20.3–31.9	19 (14.0)	9.7–19.4
Outer	53 (12.6)	10.2–15.6	98 (21.7) ^x	18.6–24.9	50 (10.2)	8.2–12.7
Other	76 (11.6)	9.6–13.7	129 (19.8) ^x	17.3–22.4	67 (10.2)	8.3–12.2
Daytime dysfunction						
	2009		2011		2012	
	n (%)	95% CI	n (%)	95% CI	n (%)	95% CI
All	157 (12.8)	11.4–14.6	295 (23.5) ^x	21.5–25.5	157 (12.3)	10.8–13.8
Gender						
Men	52 (9.7)	7.9–12.2	118 (20.6) ^x	17.9–23.5	67 (11.7)	9.6–14.0
Women	105 (15.3) ^a	13.2–17.7	177 (26.0) ^x	23.2–28.7	90 (12.7)	10.7–14.8
Age group						
20–64	116 (12.8)	10.5–16.8	232 (26.0) ^{bx}	23.5–28.3	130 (14.6) ^b	12.8–16.6
≥65	41 (13.1)	11.1–14.7	63 (17.5)	14.4–20.9	27 (6.9) ^x	4.9–9.2
Education						
Less than high school	24 (15.2)	11.1–20.5	37 (23.9) ^x	18.7–29.9	14 (10.0)	6.5–15.0
High school	76 (11.5)	9.6–13.7	143 (22.1) ^x	19.5–24.9	78 (12.0)	10.0–14.2
Junior college or higher	57 (14.1)	11.5–17.2	115 (25.5) ^x	22.2–29.0	65 (13.3)	10.9–16.0
Job groups						
Unemployed	91 (16.2) ^d	13.8–19.0	133 (23.2) ^x	20.4–26.2	70 (11.6)	9.6–13.9
Employed	66 (10.0)	8.2–12.1	162 (23.8) ^x	21.2–26.6	87 (12.9)	10.9–15.2
Disaster area						
Central	16 (11.1)	8.0–16.8	39 (25.7) ^x	20.3–31.9	21 (15.4)	10.9–21.1
Outer	59 (14.1)	11.5–17.1	111 (24.6) ^x	21.3–27.9	62 (12.7)	10.4–15.4
Other	82 (12.4)	10.5–14.7	145 (22.3) ^x	19.7–25.0	74 (11.3)	9.3–13.3
Any insomnia symptoms						
	2009		2011		2012	
	n (%)	95% CI	n (%)	95% CI	n (%)	95% CI
All	537 (43.9)	41.6–46.3	635 (50.6) ^x	48.3–52.9	545 (42.5)	40.3–44.8
Gender						

(Continued)

Table 2 (Continued).

Any insomnia symptoms						
	2009		2011		2012	
	n (%)	95% CI	n (%)	95% CI	n (%)	95% CI
Men	209 (38.8)	35.6–42.5	267 (46.6) ^x	43.1–50	229 (40.0)	36.7–43.3
Women	328 (47.9) ^a	44.8–51.0	368 (54.0) ^a	50.9–57.1	316 (44.6)	41.6–47.7
Age group						
20–64	387 (42.6)	39.9–45.3	447 (50.0) ^x	47.3–52.8	350 (39.4) ^b	36.6–42.0
≥65	150 (47.8)	43.3–52.6	188 (52.2)	47.6–56.2	195 (49.7)	45.4–53.6
Education						
Less than high school	87 (55.1) ^c	48.5–61.4	79 (51.0)	44.4–57.5	61 (43.6)	36.9–50.5
High school	294 (44.5)	41.3–47.7	335 (51.7) ^x	48.5–54.9	278 (42.7)	39.6–45.9
Junior college or higher	156 (38.6)	34.6–42.3	221 (49.0) ^x	45.2–52.9	206 (42.0)	38.4–45.7
Job groups						
Unemployed	282 (50.3) ^d	46.8–53.7	313 (54.6) ^d	51.2–58.0	294 (48.5) ^d	45.2–51.9
Employed	255 (38.5)	35.5–41.7	322 (47.3) ^x	44.2–50.4	251 (37.2)	34.2–40.3
Disaster area						
Central	54 (37.5)	31.6–44.7	73 (48.0)	41.5–54.7	65 (47.8)	40.8–54.8
Outer	205 (48.9)	44.9–52.9	230 (51.0)	45.5–53.2	198 (40.6)	37–44.3
Other	278 (42.1)	39–45.3	332 (51.0) ^x	45.7–52.1	282 (42.9)	39.8–46.1

Notes: ^xp<0.05 vs 2009, ^ap<0.05 vs men, ^bp<0.05 vs ≥65 years, ^cp<0.05 vs other education, ^dp<0.05 vs employed.

Abbreviation: CI, confidence interval.

no significant difference among the age groups before the earthquake; however, there was a notable increase in this among the younger age group immediately after and 18 months after the earthquake, which was statistically significantly higher than that observed in the older age group. On the other hand, there was no statistically significant difference in any insomnia symptoms among the age groups in 2009 and 2011. In terms of employment status, the prevalence of insomnia and daytime dysfunction was significantly higher in the unemployed than in the employed before the earthquake; however, immediately after the earthquake, this prevalence among the employed increased significantly and no difference was observed. The prevalence of any insomnia symptoms was consistently higher in the unemployed than in the employed both before and after the earthquake.

The prevalence of each insomnia symptom also increased immediately after the earthquake compared to before the earthquake. The overall prevalence of difficulty initiating sleep was significantly higher before and after the earthquake compared to other insomnia symptoms ([Supporting Table S1](#)).

Risk of Insomnia: Logistic Regression Analyses

[Table 3](#) summarizes the insomnia risk calculated using logistic regression analyses. The following factors were

associated with increased insomnia risk: being a woman (OR: 1.48, 95% CI: 1.00–2.19) and being employed in 2009 (OR: 1.74, 95% CI: 1.15–2.62). After the earthquake, gender differences in the prevalence of insomnia symptoms narrowed and the OR of insomnia among women (vs men) decreased from 1.48 times before the earthquake to 1.24 times after the earthquake, making the difference statistically non-significant.

Furthermore, in terms of age group, no significant differences were observed between the younger and older age groups before the earthquake. However, the younger age group was associated with the risk of insomnia 4 and 18 months after the earthquake (OR: 1.26, 95% CI: 0.78–2.06 in 2009, OR: 1.64, 95% CI: 1.12–2.42 in 2011, OR: 2.50 95% CI: 1.47–4.23 in 2012; for the p-values and raw ORs, see [Supporting Table S2](#)).

Mental Health Status After the Earthquake

[Table 4](#) presents the participants' post-earthquake mental health status. The K6 scores of participants with insomnia, both 4 and 18 months after the earthquake, were significantly higher than those of participants without insomnia. Compared to participants without insomnia, a significantly higher proportion of those with insomnia (men and

Table 3 Risk of Insomnia: Logistic Regression Analyses

	2009			2011			2012		
	Insomnia (+)	Insomnia (-)	Adjusted OR (95% CI)	Insomnia (+)	Insomnia (-)	Adjusted OR (95% CI)	Insomnia (+)	Insomnia (-)	Adjusted OR (95% CI)
	n (%)	n (%)		n (%)	n (%)		n (%)	n (%)	
Gender									
Men	47 (32.9)	490 (45.5)	1.00	109 (41.0)	464 (47.0)	1.00	57 (41.9)	516 (45.1)	1.00
Women	96 (67.1)	587 (54.5)	1.48 ^a (1.00–2.19)	157 (59.0)	524 (53.0)	1.24 (0.92–1.66)	79 (58.1)	629 (54.9)	1.08 (0.74–1.59)
Age									
20–64	104 (72.7)	802 (74.5)	1.26 (0.78–2.06)	205 (77.1)	689 (69.7)	1.64 ^b (1.12–2.42)	110 (80.9)	779 (68.0)	2.50 ^b (1.47–4.23)
≥65	39 (27.3)	275 (25.5)	1.00	61 (22.9)	299 (30.3)	1.00	26 (19.1)	366 (32.0)	1.00
Education									
Below high school	24 (16.8)	134 (12.4)	1.17 (0.64–2.15)	34 (12.8)	121 (12.2)	1.20 (0.73–1.96)	14 (10.3)	126 (11.0)	1.30 (0.65–2.59)
High school	70 (49.0)	589 (54.7)	0.84 (0.56–1.25)	129 (48.5)	519 (52.5)	0.89 (0.66–1.20)	66 (48.5)	585 (51.1)	0.97 (0.66–1.43)
Junior college or higher	49 (34.3)	354 (32.9)	1.00	103 (38.7)	348 (35.2)	1.00	56 (41.2)	434 (37.9)	1.00
Job groups									
Unemployed	59 (41.3)	601 (55.8)	1.00	143 (53.8)	538 (54.5)	1.00	72 (52.9)	603 (52.7)	1.00
Employed	84 (58.7)	476 (44.2)	1.74 ^a (1.15–2.62)	123 (46.2)	450 (45.5)	1.13 (0.82–1.57)	64 (47.1)	542 (47.3)	1.30 (0.86–1.97)
Disaster area									
Central	14 (9.8)	130 (12.1)	0.75 (0.41–1.38)	39 (14.7)	113 (11.4)	1.44 (0.95–2.19)	19 (14.0)	117 (10.2)	1.51 (0.87–2.63)
Outer	53 (37.1)	366 (34.0)	1.06 (0.73–1.55)	98 (36.8)	353 (35.7)	1.10 (0.81–1.48)	50 (36.8)	438 (38.3)	0.98 (0.66–1.45)
Other	76 (53.1)	581 (53.9)	1.00	129 (48.5)	522 (52.8)	1.00	67 (49.3)	590 (51.5)	1.00

Notes: p-value<0.05 was considered statistically significant; ^ap<0.05, ^bp<0.01.

Abbreviations: OR, odds ratio; CI, confidence interval.

Table 4 Post-Earthquake Mental Health Status (K6)^a

2011								
	K6 score ^b	All		Non-Insomnia		Insomnia		
		n or median	% or IQR	n or median	% or IQR	n or median	% or IQR	p
All		0	0–2	0	0–1	3	0–6	<0.01
	<5	1081	86.2%	908	91.9%	173	65.0%	<0.01
	≥5	173	13.8%	80	8.1%	93	35.0%	
Men	<5	501	87.4%	430	92.7%	71	65.1%	<0.01
	≥5	72	12.6%	34	7.3%	38	34.9%	
Women	<5	580	85.2%	478	91.2%	102	65.0%	<0.01
	≥5	101	14.8%	46	8.8%	55	35.0%	
2012								
	K6 score ^b	All		Non-Insomnia		Insomnia		
		n or median	% or IQR	n or median	% or IQR	n or median	% or IQR	p
All		1.52	0–2	0	0–1	3	1–8	<0.01
	<5	1131	88.3%	1053	92.0%	78	57.4%	<0.01
	≥5	150	11.7%	92	8.0%	58	42.6%	
Men	<5	505	88.1%	470	91.1%	35	61.4%	<0.01
	≥5	68	11.9%	46	8.9%	22	38.6%	
Women	<5	626	88.4%	583	92.7%	43	54.4%	<0.01
	≥5	82	11.6%	46	7.3%	36	45.6%	

Notes: ^aThe reported p-values are based on the χ^2 test for categorical variables and the Mann–Whitney U-test for continuous variables, comparing insomnia and non-insomnia groups. ^bThe scores range from 0 to 24 points; higher scores indicate higher distress severity. A cutoff of 5 was used to identify cases of psychological distress. **Abbreviation:** IQR, interquartile range.

women) experienced psychological distress (K6 score ≥ 5 ; 35.0% vs 8.1%) 4 months after the earthquake. There was no significant difference in the prevalence of psychological distress across genders regardless of the prevalence of insomnia. The proportion of participants with insomnia and psychological distress was higher 18 months after the earthquake than what was observed at 4 months.

Discussion

The Great East Japan Earthquake was the largest mega-earthquake recorded in and around Japan. According to the United States Geological Survey, it was the world's fourth largest earthquake since 1900. The subsequent tsunami reached a height of 40.5 meters, the highest-ever in recorded Japanese history. The death toll reached 15,899, 2529 people went missing, and 6157 were injured. Approximately 1 million homes and buildings were damaged and over 300,000 residents became evacuees. Moreover, long after the earthquake, the Fukushima nuclear accident caused significant psychological distress

among affected residents, especially mothers of infants and people working at the nuclear power plant. Reportedly, changes in physical health, including sleep and eating disorders, were also observed.²⁸

The results of this 3-wave repeated survey reveal that compared to the scenario before the earthquake (November 2009; 11.7%), the prevalence of insomnia sharply increased 4 months after the disaster (July 2011; 21.2%). Further, the prevalence of insomnia in 2011 was most notable in the central disaster area at 25.7% (November 2009; 9.7%), reaching 2.7-fold higher than before the disaster. Not as much as the central area, the rate of increase was also high in the outer (21.7%) and other disaster areas (19.8%), reaching 1.7-fold. Thus, the Great East Japan Earthquake not only triggered insomnia at extremely high rates in the central disaster area, which suffered substantial destruction but also in areas that suffered little direct damage. The marked increase in the prevalence of insomnia throughout Japan appears to have been caused by various factors, such as the sheer scale of

the earthquake, widespread damage, and prolongation of secondary damage. Sugiura et al also stated that the rate of insomnia increased immediately after the Great East Japan Earthquake, even in areas far from the epicenter, and concluded that the unsettling images shown on television and other media might have contributed to the incidence of insomnia.²⁸

Studies of affected people of large-scale natural disasters have confirmed that sleep disorders are a common occurrence. Immediately after the earthquakes that occurred in Loma Prieta, California in 1989;²⁹ Hanshin-Awaji, Japan, in 1995;³ Taiwan in 1999;⁴ Athens, Greece, in 1999;¹ Sumatra, Indonesia, in 2004;² and Kefalonia Island, Greece, in 2014,³⁰ approximately 60% of the disaster affected people experienced insomnia symptoms and nightmares (after three to eight weeks). As our 2011 survey was conducted 4 months after the earthquake, the prevalence of insomnia symptoms was lower than that in the aforementioned studies. Nevertheless, the prevalence of DIS, which was the most common symptom, exceeded 40%.

Several epidemiological studies have reported that the prevalence of insomnia symptoms is high among women.^{5,22,31–35} A similar pattern was observed in this study. However, after the earthquake, gender differences in the prevalence of insomnia symptoms narrowed, and the OR of insomnia among women (vs men) decreased after the earthquake, making the difference statistically non-significant.

In terms of age group, no significant differences were observed between the younger age group and the older age group before the earthquake. However, 4 months after the earthquake, insomnia risk among the younger age group increased sharply compared to the older age group. Moreover, 18 months later, insomnia risk among the younger age group further increased. This indicates that vulnerability to insomnia after exposure to psychological, social, and economic stress due to the Great East Japan Earthquake was higher among the younger age group. Van Griensven et al reported that symptoms of PTSD, anxiety, and depression were significantly higher in the younger age group among the Sumatra earthquake evacuees.² In addition, Kato et al reported that depressive symptoms were frequently observed in the younger age group immediately after the Hanshin-Awaji earthquake in Japan.³ Although the reason for this high prevalence of post-disaster insomnia among the younger age group is not clear, we speculate that the psychological distress of

rebuilding their lives and their families, besides finding new employment, may have been greater for the younger age group than for the older age group, who are retired and financially stable with pensions. As for the effect of employment status on insomnia, we speculate that this effect was reflected in the skewed age distribution, as the unemployed included more persons from the older age group and the employed included more from the younger age group.

However, a literature review of resilience in the elderly has shown that elderly people are not necessarily vulnerable to stress but rather are capable of high resilience.³⁷ In a recent study in Italy that examined the relationship between stressful events related to the lockdown caused by the COVID-19 pandemic and mental health, the resilience of older adults was also found to be less affected by stressful events, which may be one of the reasons for the favorable mental health outcomes seen in older adults.³⁶ These findings may partly explain the reasons for the favorable sleep and mental health outcomes observed in the elderly after the Great East Japan Earthquake in the present study.

In the context of post-disaster mental health, a higher proportion of those with insomnia immediately after the earthquake achieved scores that indicated psychological distress (≥ 5 points on the K6), strongly suggesting the deterioration of mental health problems. The prevalence of insomnia in 2012 dropped below that in 2011 and was almost the same as in 2009. In contrast, the ratio of high K6 scores worsened within the insomnia group. The prevalence rate of insomnia seems to have risen in 2011 owing to temporary stress reactions associated with the earthquake. Nonetheless, one year later, many participants with acute insomnia symptoms had recovered. However, one year after the disaster, participants with residual insomnia included many who experienced mental health problems. Oyama et al reported that being young (< 49 years), loss of contact with people in the community, and lack of employment were associated with higher prevalence of psychological distress in a survey conducted three years after the 2004 Niigata-Chuetsu earthquake.³⁸ The survey reported that the prevalence of pregnant women with psychological distress did not decrease three years after the Great East Japan Earthquake, a point that should be noted.³⁹ Suzuki et al reported that the risk of depressive tendencies was higher in men who were not working and aged < 60 years, compared with those who were working.⁴⁰ Considering that insomnia symptoms appear before

anxiety and mood disorders and that chronic insomnia increases the occurrence and risk of recurrence of such disorders,^{21,23} the outcomes for individuals with insomnia long after the earthquake must be carefully reassessed, with special attention paid to this population.

Caution must be exercised when interpreting our results. Since this was not a longitudinal study and was a three-wave repeated survey, it targeted different participants. Therefore, we could not compare the results directly and need to carefully examine whether the yearly increase/decrease trends are truly causal. Moreover, we could not obtain K6 data for the 2009 survey; this prevented a direct comparison of mental health before and after the disaster. Additionally, the earthquake cannot be considered the only contributing factor because, in most cases, the causes of insomnia are multi-layered. Needless to say, those with insomnia after an earthquake include those whose relationship to the disaster is unclear. Furthermore, there is a possibility that some of the people living in the central disaster area were not able to participate in this survey because of serious mental or physical damage. Finally, since we were unable to obtain data on the respondents' history of hospital treatment, medication, and mental illness; employment status such as shift work; economic status; loss of family and acquaintances because of the earthquake; and the presence or absence of building damage; and whether they had lost their job, we could not conduct further analysis of insomnia based on cause, or confirm how these factors impacted insomnia symptoms. Therefore, future research should utilize a survey using structured interviews with detailed questions about the participants' condition as well as evaluation tests such as polysomnography, the State-Trait Anxiety Inventory, Quick Inventory of Depressive Symptomatology, and Patient Health Questionnaire-9 to understand anxiety and depression, objectively assess sleep status, and obtain detailed information about the subjects. We would like to perform a 4th wave of research using the same methods to observe the effects 10 years after the Great East Japan Earthquake as well as the current COVID-19, in order to understand the resilience of affected people. Future studies need to demonstrate sufficient ethical considerations to avoid any additional psychological burden on the research participants who may have suffered psychological distress.

Conclusions

The 3-wave repeated survey with cross-sectional design was conducted in 2009, 2011, and 2012 to investigate the associations between the Great East Japan Earthquake and

sleep status and mental health. In the wake of the earthquake, the prevalence of insomnia increased throughout Japan and the increase was especially pronounced in the central disaster area. Additionally, the prevalence of insomnia also increased after the disaster in both men and women, but the prevalence of insomnia increased more markedly in men. Furthermore, by age, the prevalence of insomnia increased significantly in the younger age groups 4 months after the earthquake and 18 months after the earthquake. Moreover, those with insomnia included a high proportion of individuals with psychological distress, with no recovery trend observed 18 months after the earthquake. We believe that it is necessary to introduce therapeutic interventions, including psychological and physical interventions, as early as possible in order to prevent the prolongation of post-disaster insomnia and the resulting daytime dysfunction. Early detection is imperative for accurate diagnoses and appropriate treatment. Further, survivors require long-term monitoring.

Abbreviations

CI, confidence interval; DIS, difficulty initiating sleep; DMS, difficulty maintaining sleep; DSQ, deteriorated sleep quality; EMA, early morning awakening; K6, Kessler Psychological Distress Scale; OR, odds ratio.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The Akita University Graduate School of Medicine Ethics Committee approved this study (approval no. 2522).

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or

critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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