Tohoku J. Exp. Med., 2015, **237**, 83-90

Periodontal Disease Is Associated with Insomnia among Victims of the Great East Japan Earthquake: A Panel Study Initiated Three Months after the Disaster

Masahiro Tsuchiya,[1,2] Jun Aida,[3] Yoshihiro Hagiwara,[4] Yumi Sugawara,[5,6] Yasutake Tomata,[5] Mari Sato,[6,7] Takashi Watanabe,[5] Hiroaki Tomita,[8] Eiji Nemoto,[9] Makoto Watanabe,[1] Ken Osaka[3,10] and Ichiro Tsuji[5,6]

[1]Tohoku Fukushi University, Sendai, Miyagi, Japan
[2]Division of Oral Diagnosis, Tohoku University Graduate School of Dentistry, Sendai, Miyagi, Japan
[3]Division of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Sendai, Miyagi, Japan
[4]Department of Orthopaedic Surgery, Tohoku University School of Medicine, Sendai, Miyagi, Japan
[5]Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan
[6]Center for Community Health, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan
[7]Department of Women's Health Nursing, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan
[8]Department of Disaster Psychiatry, Internal Research Institute of Disaster Science, Tohoku University, Sendai, Miyagi, Japan
[9]Division of Periodontology and Endodontology, Tohoku University Graduate School of Dentistry, Sendai, Miyagi, Japan
[10]Tohoku University International Research Institute of Disaster Science, Sendai, Miyagi, Japan

In March 2011, the Great East Japan Earthquake (GEJE), which was followed by a devastating tsunami, destroyed the societal and the public hygiene systems in Japanese coastal areas. Insomnia, the greatest issue among disaster victims, has detrimental effects on both physical and psychological health. Periodontitis causes chronic discomfort and inflammation, and little is known about its impact on insomnia. Three months after the earthquake, a health panel survey was conducted over four surveys, till September 2013, in which information regarding 8,015 adults was collected and used. In addition to the heath-related questionnaire, other variables including subjective symptoms of oral diseases were recorded, and the Athens Insomnia Scale was used to evaluate the severity of insomnia. The association between insomnia and periodontal disease was examined using multilevel logistic models on the panel data, after adjusting for sex, age, economic status, comorbidities, body mass index, post-traumatic stress reactions, habitual smoking and alcohol drinking, and the Kessler Psychological Distress Scale score. In addition to the higher prevalence of insomnia among GEJE victims, significant association was revealed between insomnia and gum problems (OR = 2.16, 95% CI = 1.43-3.26), and difficulty chewing (OR = 2.22, 95% CI = 1.40-3.51), after adjusting for all covariates. The present study revealed significant association between insomnia and periodontal disease among GEJE victims. This indicated that together, integrated oral health care for disaster victims would contribute not only to prevention of oral infectious diseases, but may also help alleviate other problems caused by these harmful events.

Keywords: insomnia; large-scale disaster; oral health; panel study; periodontal disease
Tohoku J. Exp. Med., 2015 October, **237** (2), 83-90.

Introduction

The Great East Japan Earthquake (GEJE), a large earthquake of 9.0 magnitude on the Richter scale, which was followed by a devastating tsunami, destroyed the eastern coastal towns and villages of Japan on March 11, 2011 (Ishigaki et al. 2013). This was the greatest disaster ever recorded in Japan in which more than 18,000 people were reported dead or missing, and an additional 6,000 people were injured. The disaster also affected over 20 prefectures, including Miyagi, and almost 400,000 buildings were damaged or destroyed. In April 2014, there were still more

Received May 21, 2015; revised and accepted August 31, 2015. Published online September 17, 2015; doi: 10.1620/tjem.237.83.
Correspondence: Jun Aida, Division of International and Community Oral Health, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8575, Japan.
e-mail: j-aida@umin.ac.jp

than 260,000 evacuees throughout Japan, especially in Miyagi, where approximately 85,000 evacuees lived in about 20,000 temporary units (Below et al. 2012; Ishigaki et al. 2013). It is widely recognized that natural disasters cause major public health problems owing to the impact of the environmental changes associated with the collapse of the societal and public hygiene systems (Cherniack 2008; Kako et al. 2014).

Under the severe conditions experienced following a large-scale disaster, oral hygiene deteriorates, which increases the risk of oral diseases such as dental caries and periodontal disease (Liu et al. 2010; Hosokawa et al. 2012). A cross-sectional study reported that declining oral hygiene caused by the Wenchuan earthquake in Southwest China exacerbated periodontitis in elderly victims (Liu et al. 2010). Under these conditions, integrated oral health care could prevent not only oral diseases but also oral infectious diseases like pneumonia and influenza (Adachi et al. 2007; Estupinan-Day et al. 2011; Yamamoto 2013). In addition, psychological stress, such as depression and anxiety experienced by disaster victims, is strongly associated with the progression of periodontal disease (Lopez et al. 2012; Cakmak et al. 2014).

Insomnia, characterized by a difficulty in falling asleep and/or maintaining sleep, is one of the most frequent symptoms following disasters (Lavie 2001; Mohsenin and Mohsenin 2014). It has been a great issue among GEJE victims (Matsumoto et al. 2014). Insomnia is recognized as the most common sleep disorder that has detrimental effects on both psychological and physiological health (Babson and Feldner 2010; Piccolo et al. 2013). Recently, epidemiological studies on patients, and their meta-analyses, have revealed a significant and bidirectional relationship between periodontal disease and obstructive sleep apnea, a sleep disorder (Al-Jewair et al. 2015). With respect to the potential mechanism in connecting the two diseases, however, only one an animal study has examined the unidirectional impact and indicated that sleep deprivation and the associated psychological fatigue exacerbated experimental periodontitis (Nakada et al. 2015). Therefore, it is still unclear how periodontal disease could affect sleep disorders. In this context, the comorbidity rate of insomnia in obstructive sleep apnea patients was approximately 40-60% (Luyster et al. 2010; Bjorvatn et al. 2014). However, little is known about the association of periodontal disease with insomnia in disaster-affected populations.

We hypothesized that the deterioration of oral hygiene in GEJE victims resulted in the progression of periodontal diseases along with insomnia. Here, using the panel data from repeated surveys in the GEJE- and tsunami-affected areas, we sought to clarify the association between periodontal diseases and insomnia after the large-scale disaster, after adjusting for baseline covariates, including psychological stress. The results could determine important targets for dental intervention and strategies to support the disaster victims.

Methods

Study population

A panel study was conducted semi-annually with GEJE victims, from June 2011, three months after the disaster, until September 2013 (across four phases: June to September 2011, October 2011 to February 2012, October 2012 to February 2013, and May to September 2013) by the Tohoku University Graduate School of Medicine. Five coastal areas in the Miyagi prefecture, namely, Wakabayashi-ku in Sendai; Ajishima, Ogatu, and Oshika in Ishinomaki city; and Shichigahama-cho, were selected based on discussions with local governments. We recruited subjects aged 18 years and older (as of June, 2011) based on data from the Basic Resident Registration system in each area, as well as those who had previously participated in health surveys, whose subsequent address has been known until May 2013. A self-administered questionnaire was mailed to the participants. Among the 31,009 residents aged 18 years or older (9,412, 7,663, 6,927, and 7,007 for each survey, respectively), the numbers of respondents and response rates for each of the four survey periods were 4,095 (43.8%), 1,874 (24.5%), 2,412 (34.8%), and 3026 (43.2%), respectively. After excluding invalid responses (e.g. missing of the agreement to participate into the survey), data on 8,015 individuals were included in the analysis.

Outcome variable

The Athens Insomnia Scale (AIS), a standardized self-assessment instrument based on ICD-10 criteria for insomnia, was used to assess the outcome variable, insomnia. It was administered as a self-reported questionnaire. The cut-off value of 6 points or more was utilized to establish the diagnosis of insomnia (Okajima et al. 2013).

Main predictors

Oral health-related symptoms ("toothache," "swollen or bleeding gums," and "difficulty in chewing") were determined through a self-reported questionnaire. These yes or no questions were derived from the Comprehensive Survey of Living Conditions, which is a national survey that is conducted in Japan (Ministry of Health, Labour and Welfare 2009; Hiyoshi et al. 2014). Use of this questionnaire also enabled a comparison of the present findings on disaster victims with the responses derived from a national sample in Japan.

Covariates

Socio-demographic characteristics, lifestyle, and health condition variables were recorded and the following were included in the analyses as covariates: sex, age, economic status, comorbidity, post-traumatic stress reactions (PTSRs), smoking habits, alcohol drinking, and the score on the Kessler Psychological Distress Scale (K6) (Kessler et al. 2002). In addition, body mass index (BMI) was measured in health examinations carried out along with this survey. These covariates have been recognized as predictor variables for insomnia/sleep disorders in previous studies (Palm et al. 2015). The participants were divided into the following groups by age: 29 years or younger, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-79 years, and 80 years or older. The economic status was obtained using the following self-reported question: "How do you feel about the current economic condition of your household?" The response alternatives were "poorest," "poorer," "poor," or "fair." Comorbidities were surveyed by determining is they had recently undergone any medical treatments for stroke, diabetes, hypertension, and coronary heart dis-

ease (CHD). BMI was categorized into 4 groups (less than 18.5, 18.5-24.9, 25-29.9, 30 or more). PTSR was determined using the following 3 yes or no questions: "Are you experiencing any repeated, disturbing memories and/or dreams?", "Do you feel very upset when something reminds you of a stressful experience from the earthquake?", and "Do you have any physical reactions (e.g., heart pounding, trouble breathing, sweating, or dizziness) when something reminds you of a stressful experience from the earthquake?". Habitual smoking and alcohol drinking were determined. Psychological distress was assessed using the continuous K6 score. We used the Japanese version of the K6, which was developed through a standard back-translation procedure and has been validated (Furukawa et al. 2008).

Statistical analysis

In our data set, observations in each survey period were nested in individuals; therefore, a multilevel logistic analysis was applied to calculate the odds ratio (OR) and 95% confidential intervals (95% CI) for insomnia. This analysis was used to compensate for any missing observations in any of the panels (Hox 2010). At first, we calculated univariate ORs for each variable with reference to the insomnia level. In the covariate-adjusted models, we assessed the effect of each variable on insomnia, after adjusting for age, sex, economic status, comorbidity, oral health symptoms, BMI, PTSR, smoking habit, alcohol consumption, and the K6 score. To analyze missing data, we applied the "missing at random" assumption, and used multiple imputation with the multivariate normal imputation method (Cummings 2013). In the imputation models, variables in the main analysis and variables on comorbidities were included. Analyses were independently applied for 10 copies of the data, each with missing values suitably imputed. Estimates of the variables were averaged to compute a single mean estimate and adjusted standard errors using the Rubin's rule (Rubin 1987). The numbers of participants without missing data in each question have been shown in Table 1. The STATA version 13.1 (Stata Corp., College Station, TX, USA) was used for all analyses, and statistical significance was declared at $p < 0.05$.

Ethical considerations

The study protocol was reviewed and approved by the Ethics Committee on Research of Human Subjects at the Tohoku University Graduate School of Medicine (approved number: 201192 and 2014157). We explained the aims of the study to all participants, after which their written informed consent was obtained.

Results

The numbers of participants with valid in each of the four survey periods were 3,555, 1,511, 1,303, and 1,646, respectively. The insomnia prevalence with reference to each risk factor in all the participants has been shown in Table 1. Note that 580 out of the 8,015 participants missed the AIS data. The average prevalence of insomnia was 38.9%. In all the survey periods, the percentages of participants who reported toothache, gum problems, or difficulty in chewing were 4.2%, 4.2%, and 3.4%, respectively. Further, participants with oral health-related symptoms had remarkably higher prevalence rates of insomnia compared with participants without the symptom (toothache: 60.3% vs. 38.0%, gum problems: 65.3% vs. 37.7%, difficulty chewing: 71.8% vs. 37.7%, respectively). Survey participants who were in the middle age group (approximately 45% vs. 25.8% in the youngest group), were female (43.1%

Table 1. Characteristics of subjects and insomnia incidence in the survey: Areas experienced by Great East Japan Earthquake in Miyagi, Japan, 2011-2013.

Variables	N	Insomnia incidence, N (%)
Age (years)		
17-29	429	115 (26.8)
30-39	478	166 (34.7)
40-49	774	349 (45.1)
50-59	1,284	588 (45.8)
60-69	2,017	823 (40.8)
70-79	1,805	641 (35.5)
≥ 80	648	210 (32.4)
Gender		
Male	3,365	1,139 (33.8)
Female	4,070	1,753 (43.1)
Economic status		
Fair	3,003	758 (25.2)
Poor	2,054	879 (42.8)
Poorer	1,526	776 (50.9)
Poorest	800	452 (56.5)
Comorbidity		
Stroke	107	42 (39.3)
Diabetes	576	224 (38.9)
Hypertension	2,483	966 (38.9)
CHD	392	183 (46.7)
Oral symptoms		
Toothache	310	187 (60.3)
Gum problems	14	205 (65.3)
Difficulty chewing	255	183 (71.8)
BMI		
Less than 18.5	174	59 (33.9)
18.5-24.9	2,978	1,117 (37.5)
25.0-29.9	1,577	617 (39.1)
30 or more	300	121 (40.3)
PTSR		
Intrusion	2,442	1,418 (58.1)
Agitated	2,311	1,435 (62.1)
Hyperarousal	877	643 (73.3)
Habits		
Smoking	1,517	610 (40.2)
Alcohol drinking	2,565	908 (35.4)
Total	7,435	2,892 (38.9)
Missing for AIS	580	
K6 score	N	Average ± SD
Non-Insomnia	4,322	3.2 ± 3.5
Insomnia	2,725	8.0 ± 4.8

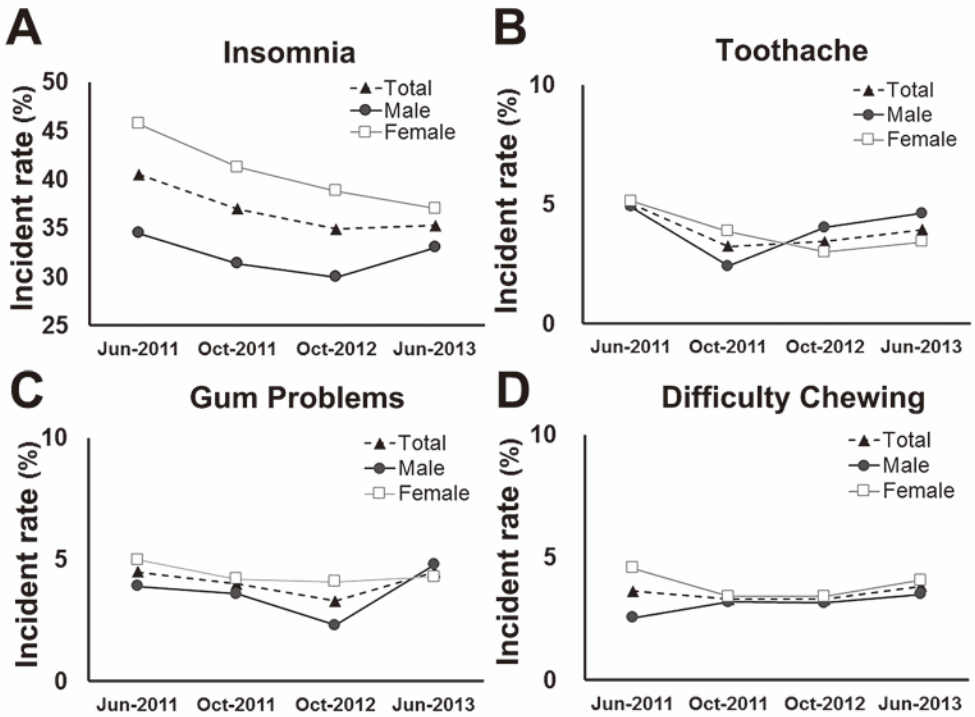

Fig. 1. Unadjusted average prevalence of insomnia and oral health-related symptoms.
Unadjusted average prevalence of insomnia (A) and oral health-related symptoms of toothache (B), gum problems (C), and difficulty chewing (D) by survey period. In both males and females, prevalence of insomnia was the highest at three months after the Great East Japan Earthquake and recovery was slow until October 2012. In males, the prevalence of insomnia, of toothache, and of gum problems increased again in June 2013.

vs. 33.8% in male), were from the lower economic status (approximately 50% vs. 25.2% in fair status), or had some PTSR variables (approximately 60-70% vs. 38.9% on the baseline value) showed higher prevalence of insomnia. Fig. 1 shows the unadjusted average prevalence of insomnia and of oral health-related symptoms during the survey period. The survey over two and a half years indicated a consistent and higher prevalence of insomnia (Fig. 1A) and of gum problems (Fig. 1C) in participants, especially in females (insomnia: 43.1% vs. 33.8%, gum problems: 4.4% vs. 3.7% in male participants, respectively). In addition, the prevalence of insomnia, of toothache and of gum problems only in male participants recently increased in June 2013 again.

Table 2 shows the covariate-adjusted ORs for each of the risk factor related to insomnia. The univariate models using multiple imputation revealed significantly higher ORs for all oral health-related variables (toothache: OR = 2.88, 95% CI = 1.90-4.36; gum problems: OR = 4.50, 95% CI = 2.97-6.81; difficulty chewing: OR = 5.55, 95% CI = 3.53-8.73, $p < 0.001$, respectively). When adjusted for covariates, the trends and significant relationships among participants were also similar. In addition to other risk factors such as age, sex, economic status, PTSRs, alcohol consumption, and psychological distress condition, multivariate logistic regression analyses showed that participants with each oral complaint (gum problems and difficulty chewing) had significantly higher ORs for insomnia as compared with those without oral complaints (OR = 2.16, 95% CI = 1.43-3.26, $p < 0.001$ and OR = 2.22, 95% CI = 1.40-3.51, $p < 0.01$, respectively). Surprisingly, the ORs for gum problems or difficulty in chewing associated with insomnia were similar to the ORs of the PTSRs. There was, however, no significant association between insomnia and toothache after adjusting for covariates ($p = 0.41$). Note that the multilevel logistic analysis without multiple imputation, the complete case analysis indicated the similar significant associations between each oral symptom and insomnia. The adjusted ORs of toothache, gum problems, and difficulty in chewing on insomnia were 1.47 (95% CI = 1.13-1.86, $p = 0.004$), 2.18 (95% CI = 1.68-2.82, $p < 0.001$) and 2.38 (95% CI = 1.78-3.18, $p < 0.001$), respectively.

Discussion

The present results revealed that two oral health problems, i.e., gum problems and difficulty in chewing, were strongly associated with the insomnia prevalence in a large-population of the 2011 GEJE victims of the Tsunami, but toothache was not. Further, the prevalence of self-reported oral health-related symptoms among the GEJE victims was almost two times higher than that found in a 2013 nationwide survey that was conducted using same questionnaires (Ministry of Health, Labour and Welfare 2013). Indeed, as observed in Fig. 1, so far from achieving to the national baseline in Japan, the prevalence of oral symptoms among

Table 2. Adjusted odds ratios and 95% confidence intervals for insomnia.

Variables		Multivariate adjusted[1]	
		OR	95% CI
Complaint of oral health			
Toothache	N	1.00	
	Y	1.18	(0.77-1.79)
Gum problems	N	1.00	
	Y	***2.16	(1.43-3.26)
Difficulty chewing	N	1.00	
	Y	**2.22	(1.40-3.51)
Age (years)			
17-29		1.00	
30-39		*1.79	(1.07-2.97)
40-49		***3.68	(2.34-5.81)
50-59		***3.86	(2.49-5.98)
60-69		***2.95	(1.94-4.50)
70-79		**1.82	(1.17-2.82)
≥ 80		1.65	(0.99-2.77)
Gender			
Male		1.00	
Female		**1.37	(1.11-1.68)
Economic status			
Fair		1.00	
Poor		***1.82	(1.49-2.21)
Poorer		***2.02	(1.62-2.52)
Poorest		***2.24	(1.69-2.98)
Comorbidity			
Stroke	N	1.00	
	Y	0.89	(0.43-1.83)
Diabetes	N	1.00	
	Y	0.99	(0.70-1.40)
Hypertension	N	1.00	
	Y	1.02	(0.83-1.26)
CHD	N	1.00	
	Y	1.44	(0.95-2.18)
BMI			
Less than 18.5		1.00	
18.5-24.9		1.08	(0.65-1.78)
25.0-29.9		1.10	(0.65-1.86)
30 or more		1.00	(0.56-1.80)
PTSR			
Intrusion	N	1.00	
	Y	***1.73	(1.44-2.08)
Agitated	N	1.00	
	Y	***1.74	(1.42-2.15)
Hyperarousal	N	1.00	
	Y	**1.63	(1.24-2.15)
Habits			
Smoking	N	1.00	
	Y	0.91	(0.72-1.16)
Alcohol consumption	N	1.00	
	Y	*1.27	(1.02-1.57)
K6 score			
(per 1 point increase)		***1.34	(1.30-1.37)

Y, Yes; N, No.

Multiple imputation logistic regression: Areas experienced by the Great East Japan Earthquake in Miyagi, Japan, 2011-2013.

[1]Adjusted for age, sex, economic status, comorbidity, complaint of oral health, BMI, PTSR, smoking, alcohol consumption and K6 score.

Statistically significant variable (*$p < 0.05$, **$p < 0.01$ and ***$p < 0.001$).

GEJE victims recently tended to increase again. The increase in the oral symptoms related to periodontal disease leads us to assume that it is linked to the deterioration of oral hygiene among victims after the GEJE. Periodontal disease, a major chronic infectious disease, can also be exacerbated by psychological stress and depression followed by the dysregulation of the cellular and humoral pathways of the immune system (Okada et al. 2010; Warren et al. 2014). Similarly, sleep disturbances increase with psychological stress and infectious diseases (Irwin 2015). Thus, psychological stress is certainly one of the most potent confounding factors related to both periodontal disease and insomnia. The statistical correlation between periodontal disease and insomnia was attenuated, but it remained strong even after adjusting for the psychological covariates of the K6 score and PTSRs. Furthermore, the ORs for the oral symptoms of periodontal disease with reference to insomnia were similar to those of PTSRs. Although this study could not distinctly define the relationship between periodontal disease and insomnia because of less temporal data, our findings support the fact that there are other potential factors that affect the meaningful link between periodontal disease and insomnia. A future study using periodontal intervention with insomnia patients may clarify the mechanism involved in the development of the disease.

Of the 8,015 subjects participating in the present study, 38.9% (2,892 participants, with 580 missing data) were classified as suffering from insomnia. Thus, the insomnia prevalence observed in this study population was higher than that reported from other surveys conducted in Japan using the AIS (23.0-27.3% in males and 31.0-34.4% in females), but lower than that reported in non-emergency conditions (Utsugi et al. 2005; Yoshioka et al. 2012; Saijo et al. 2015). Meanwhile, the prevalence rates of insomnia after a great earthquake were reportedly 63% and 46% at 3 and 8 weeks after Hanshin-Awaji earthquake, respectively, and 60% a year after the 1999 Athens earthquake in Greece (Kato et al. 1996; Varela et al. 2008). Indeed, these studies showed higher values than those reported in the present survey. These discrepancies may be due to the longer survey periods or the lower response rate in this survey, because non-respondents tended to shows poorer health status.

The multivariable logistic analysis could further show the significant associations between insomnia and its demographic risk factors such as being female, in a difficult economic situation, and being in serious psychological stress (screened by the PTSR and K6 scores) (Lazaratou et al. 2012). The present study revealed the highest OR for insomnia in middle-aged participants (50s), which differs from that reported by previous studies, which showed that the highest prevalence of insomnia was in elderly people, majorly cause by aging. Although specific reasons for the highest prevalence of insomnia in the middle-aged group were not determined in this study, previous studies indicated that the psychological stress and depressive reactions among the disaster victims after GEJE was distinctly observed in the middle-aged group (Koyama et al. 2014; Matsubara et al. 2014). Evident from the delayed increase of suicide rates in middle-aged GEJE victims in the disaster-affected areas (Orui et al. 2015), continuous and intensive healthcare services are worth considering in support of these people.

In terms of the limitations of this study, first, the survey revealed low response rates in each panel, possibly owing to the unstable home addresses of most participants after the GEJE. Indeed, as indicated by the largest number of participants in the first survey, panel studies typically suffer from attrition, which pretend the higher response rate in the initial survey as biased inferences (Cheng and Trivedi 2015). Therefore, we cannot rule out the possibility of a selection bias. Meanwhile, since most people who do not respond tend to have a poorer health status, the association examined in the present study might be stronger in the non-respondents. Second, the subjects of this study were all disaster victims who were suffering from great psychological trauma. Therefore, it is unknown whether our results are applicable to the general population. Therefore, a future study with an appropriate design needs to be performed on the general population. Third, we did not conduct a standardized clinical periodontal examination, which could quantify the periodontal status and strengthen the intra-disease associations. However, the strength of our study is that it was a large-scale panel study on disaster victims. Natural disasters induce several public health issues. However, few studies have focused on the impact of oral health. Therefore, this study would be important in the public health field. In addition, our results could be the first to suggest the possibility of the impact of oral health on insomnia among disaster victims. As a public health implication, this indicates that a wider range of health care intervention including oral health care may be important after disasters.

In conclusion, our large-scale panel study on GEJE victims determined a strong association between periodontal disease and insomnia. This implies that reciprocal management for sleep disorders and periodontal disease would reduce intra-disease actions, which may contribute to the victims' systemic health. However, the underlying mechanism remains unclear, and adequate additional clinical research is necessary to confirm our findings.

Acknowledgments

This study was supported by Tohoku University Graduate School of Dentistry and Center for Community Health, Tohoku University Graduate School of Medicine, and by Health Labour Sciences Research Grants, H24-Kenki-Shitei-002, H25-Kenki-Shitei-002 (Fukko), from the Japanese Ministry of Health, Labour and Welfare, by the MEXT-Supported Program for the Strategic Research Foundation at Private Universities to the Kansei Fukushi Research Institute, Tohoku Fukushi University (2012-2016), and also by grants from the Japan Society for the Promotion of Science, 23390439, 24390429, and 25670813.

Author Contributions

J.A., Y.S., Y.T., M.S., K.O., and I.T. participated in data acquisition. M.T., J.A., and Y.H. developed the concept of the study and participated in its design. T.W., M.W., H.T., and E.N. helped develop the concept of the study. M.T., J.A., Y.H., Y.T., K.O., and I.T. critically revised the manuscript. All authors have read and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

References

Adachi, M., Ishihara, K., Abe, S. & Okuda, K. (2007) Professional oral health care by dental hygienists reduced respiratory infections in elderly persons requiring nursing care. *Int. J. Dent. Hyg.*, **5**, 69-74.

Al-Jewair, T.S., Al-Jasser, R. & Almas, K. (2015) Periodontitis and obstructive sleep apnea's bidirectional relationship: a systematic review and meta-analysis. *Sleep Breath*, [Epub ahead of print].

Babson, K.A. & Feldner, M.T. (2010) Temporal relations between sleep problems and both traumatic event exposure and PTSD: a critical review of the empirical literature. *J. Anxiety Disord.*, **24**, 1-15.

Below, R., Guha-Sapir, D., Ponserre, S. & Vos, F. (2012) Annual disaster statistical review 2011: the numbers and trends, CRED, Brussels, Belgium.

Bjorvatn, B., Pallesen, S., Gronli, J., Sivertsen, B. & Lehmann, S. (2014) Prevalence and correlates of insomnia and excessive sleepiness in adults with obstructive sleep apnea symptoms. *Percept. Mot. Skills*, **118**, 571-586.

Cakmak, O., Alkan, B.A., Ozsoy, S., Sen, A. & Abdulrezzak, U. (2014) Association of gingival crevicular fluid cortisol/dehydroepiandrosterone levels with periodontal status. *J. Periodontol.*, **85**, e287-294.

Cheng, T.C. & Trivedi, P.K. (2015) Attrition bias in panel data: a sheep in wolf's clothing? A case study based on the MABEL survey. *Health Econ.*, **24**, 1101-1117.

Cherniack, E.P. (2008) The impact of natural disasters on the elderly. *Am. J. Disaster Med.*, **3**, 133-139.

Cummings, P. (2013) Missing data and multiple imputation. *JAMA Pediatr.*, **167**, 656-661.

Estupinan-Day, S., Lafontant, C. & Acuna, M.C. (2011) Integrating oral health into Haiti's National Health Plan: from disaster relief to sustainable development. *Rev. Panam. Salud Publica*, **30**, 484-489.

Furukawa, T.A., Kawakami, N., Saitoh, M., Ono, Y., Nakane, Y., Nakamura, Y., Tachimori, H., Iwata, N., Uda, H., Nakane, H., Watanabe, M., Naganuma, Y., Hata, Y., Kobayashi, M., Miyake, Y., et al. (2008) The performance of the Japanese version of the K6 and K10 in the World Mental Health Survey Japan. *Int. J. Methods Psychiatr. Res.*, **17**, 152-158.

Hiyoshi, A., Fukuda, Y., Shipley, M.J. & Brunner, E.J. (2014) Health inequalities in Japan: the role of material, psychosocial, social relational and behavioural factors. *Soc. Sci. Med.*, **104**, 201-209.

Hosokawa, R., Taura, K., Ito, E. & Koseki, T. (2012) Roles of dentists and dental hygienists in two major earthquakes. *Int. Dent. J.*, **62**, 315-319.

Hox, J.J. (2010) *Multilevel analysis: techniques and applications*, 2nd ed., Routledge, New York, NY.

Irwin, M.R. (2015) Why sleep is important for health: a psychoneuroimmunology perspective. *Annu. Rev. Psychol.*, **66**, 143-172.

Ishigaki, A., Higashi, H., Sakamoto, T. & Shibahara, S. (2013) The Great East-Japan Earthquake and devastating tsunami: an update and lessons from the past Great Earthquakes in Japan since 1923. *Tohoku J. Exp. Med.*, **229**, 287-299.

Kako, M., Arbon, P. & Mitani, S. (2014) Disaster health after the 2011 great East Japan earthquake. *Prehosp. Disaster Med.*, **29**, 54-59.

Kato, H., Asukai, N., Miyake, Y., Minakawa, K. & Nishiyama, A. (1996) Post-traumatic symptoms among younger and elderly evacuees in the early stages following the 1995 Hanshin-Awaji earthquake in Japan. *Acta Psychiatr. Scand.*, **93**, 477-481.

Kessler, R.C., Andrews, G., Colpe, L.J., Hiripi, E., Mroczek, D.K., Normand, S.L., Walters, E.E. & Zaslavsky, A.M. (2002) Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol. Med.*, **32**, 959-976.

Koyama, S., Aida, J., Kawachi, I., Kondo, N., Subramanian, S.V., Ito, K., Kobashi, G., Masuno, K., Kondo, K. & Osaka, K. (2014) Social support improves mental health among the victims relocated to temporary housing following the Great East Japan Earthquake and Tsunami. *Tohoku J. Exp. Med.*, **234**, 241-247.

Lavie, P. (2001) Sleep disturbances in the wake of traumatic events. *N. Engl. J. Med.*, **345**, 1825-1832.

Lazaratou, H., Soldatou, A. & Dikeos, D. (2012) Medical comorbidity of sleep disorders in children and adolescents. *Curr. Opin. Psychiatry*, **25**, 391-397.

Liu, D., Hu, D., Li, X. & Ma, H. (2010) Periodontitis in 65-74-year-old victims in Wenchuan, China post-earthquake: implications for service provision. *Int. Dent. J.*, **60**, 161-168.

Lopez, R., Ramirez, V., Marro, P. & Baelum, V. (2012) Psychosocial distress and periodontitis in adolescents. *Oral Health Prev. Dent.*, **10**, 211-218.

Luyster, F.S., Buysse, D.J. & Strollo, P.J. Jr. (2010) Comorbid insomnia and obstructive sleep apnea: challenges for clinical practice and research. *J. Clin. Sleep Med.*, **6**, 196-204.

Matsubara, C., Murakami, H., Imai, K., Mizoue, T., Akashi, H., Miyoshi, C. & Nakasa, T. (2014) Prevalence and risk factors for depressive reaction among resident survivors after the tsunami following the Great East Japan Earthquake, March 11, 2011. *PLoS One*, **9**, e109240.

Matsumoto, S., Yamaoka, K., Inoue, M. & Muto, S.; Teikyo Ishinomaki Research Group and Health and Life Revival Council in the Ishinomaki dustrict (RCI) (2014) Social ties may play a critical role in mitigating sleep difficulties in disaster-affected communities: a cross-sectional study in the Ishinomaki area, Japan. *Sleep*, **37**, 137-145.

Ministry of Health, Labour and Welfare (2009) Comprehensive survey of living conditions. http://www.mhlw.go.jp/english/database/db-hss/cslc.html [*Accessed*: October 24, 2014].

Ministry of Health, Labour and Welfare (2013) Overview of the comprehensive survey of living conditions. Statistics: Table 9 subjective symptoms. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa13/dl/06.pdf [*Accessed*: October 24, 2014].

Mohsenin, S. & Mohsenin, V. (2014) Diagnosis and management of sleep disorders in posttraumatic stress disorder:a review of the literature. *Prim. Care Companion CNS Disord.*, **16**.

Nakada, T., Kato, T. & Numabe, Y. (2015) Effects of fatigue from sleep deprivation on experimental periodontitis in rats. *J. Periodontal Res.*, **50**, 131-137.

Okada, Y., Hamada, N., Kim, Y., Takahashi, Y., Sasaguri, K., Ozono, S. & Sato, S. (2010) Blockade of sympathetic b-receptors inhibits Porphyromonas gingivalis-induced alveolar bone loss in an experimental rat periodontitis model. *Arch. Oral Biol.*, **55**, 502-508.

Okajima, I., Nakajima, S., Kobayashi, M. & Inoue, Y. (2013) Development and validation of the Japanese version of the Athens Insomnia Scale. *Psychiatry Clin. Neurosci.*, **67**, 420-

425.
Orui, M., Sato, Y., Tazaki, K., Kawamura, I., Harada, S. & Hayashi, M. (2015) Delayed increase in male suicide rates in tsunami disaster-stricken areas following the great east japan earthquake: a three-year follow-up study in Miyagi Prefecture. *Tohoku J. Exp. Med.*, **235**, 215-222.
Palm, A., Janson, C. & Lindberg, E. (2015) The impact of obesity and weight gain on development of sleep problems in a population-based sample. *Sleep Med*., **16**, 593-597.
Piccolo, R.S., Yang, M., Bliwise, D.L., Yaggi, H.K. & Araujo, A.B. (2013) Racial and socioeconomic disparities in sleep and chronic disease: results of a longitudinal investigation. *Ethn. Dis*., **23**, 499-507.
Rubin, D.B. (1987) *Multiple imputation for nonresponse in surveys*, John Wiley & Sons, New York, NY.
Saijo, Y., Chiba, S., Yoshioka, E., Nakagi, Y., Ito, T., Kitaoka-Higashiguchi, K. & Yoshida, T. (2015) Synergistic interaction between job control and social support at work on depression, burnout, and insomnia among Japanese civil servants. *Int. Arch. Occup. Environ. Health*, **88**, 143-152.
Utsugi, M., Saijo, Y., Yoshioka, E., Horikawa, N., Sato, T., Gong, Y. & Kishi, R. (2005) Relationships of occupational stress to insomnia and short sleep in Japanese workers. *Sleep*, **28**, 728-735.
Varela, E., Koustouki, V., Davos, C.H. & Eleni, K. (2008) Psychological consequences among adults following the 1999 earthquake in Athens, Greece. *Disasters*, **32**, 280-291.
Warren, K.R., Postolache, T.T., Groer, M.E., Pinjari, O., Kelly, D.L. & Reynolds, M.A. (2014) Role of chronic stress and depression in periodontal diseases. *Periodontol. 2000*, **64**, 127-138.
Yamamoto, R. (2013) "Let me check your mouth": the way to open ones' heart the 3.11 Great East Japan Earthquake, oral health support program in Minami Sanriku-cho, Miyagi Prefecture. *Sangyo Eiseigaku Zasshi*, **55**, 111-114.
Yoshioka, E., Saijo, Y., Kita, T., Satoh, H., Kawaharada, M., Fukui, T. & Kishi, R. (2012) Gender differences in insomnia and the role of paid work and family responsibilities. *Soc. Psychiatry Psychiatr. Epidemiol.*, **47**, 651-662.