BMJ Open

Effect of large-scale disasters on bystander-initiated cardiopulmonary resuscitation in family-, friend-, and colleague-witnessed out-of-hospital cardiac arrest: a retrospective analysis of prospectively collected, nationwide, population-based data of out-of-hospital cardiac arrest cases

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-055640
Article Type:	Original research
Date Submitted by the Author:	19-Jul-2021

Complete List of Authors:	Ushimoto, Tomoyuki; Kanazawa Medical University, Emergency Medicine Takada, Kohei; Kanazawa University Graduate School of Medical Sciences, Department of Circulatory Emergency and Resuscitation Science Yamashita, Akira; Kanazawa University Graduate School of Medical Sciences, Department of Circulatory Emergency and Resuscitation Science; Noto General Hospital, Department of Cardiology Morita, Hideki; Kanazawa Medical University, Department of Emergency Medicine Wato, Yukihiro; Kanazawa Medical University, Emergency medicine Inaba, Hideo; Kanazawa Medical University, Emergency Medicine; Kanazawa Medical University, Department of Emergency Medicine

Keywords:	ACCIDENT & EMERGENCY MEDICINE, EDUCATION & TRAINING (see Medical Education & Training), MEDICAL EDUCATION & TRAINING, PUBLIC HEALTH

Effect of large-scale disasters on bystander-initiated cardiopulmonary resuscitation in family-, friend-, and colleague-witnessed out-of-hospital cardiac arrest: a retrospective analysis of prospectively collected, nationwide, population-based data of out-of-hospital cardiac arrest cases

Tomoyuki Ushimoto, MD, PhD[1] (0000-0002-9060-9391), Kohei Takada, BA[2], Akira Yamashita, MD, PhD[2,3], Hideki Morita, MD[1], Yukihiro Wato, MD, PhD[1], Hideo Inaba, MD, PhD[1,4]

[1]Department of Emergency Medicine, Kanazawa Medical University, Uchinada, Japan

[2]Department of Circulatory Emergency and Resuscitation Science, Kanazawa University Graduate School of Medicine, Kanazawa, Japan

[3]Department of Cardiology, Noto General Hospital, Nanao, Japan

[4]Kanazawa University, Kanazawa, Japan

E-mail addresses:

TU; ushi@kanazawa-med.ac.jp, KT; tatatakakakadadada612@yahoo.co.jp, AY; yamashita@noto-hospital.jp, HM; moririn@p2223.nsk.ne.jp, YW; allstar@kanazawa.med.ac.jp, HI; mauriakoi@ybb.ne.jp

*Address for correspondence:

Tomoyuki Ushimoto, MD, PhD, Assistant Professor of Emergency Medicine, Kanazawa Medical University

1-1 Daigaku, Uchinada-machi, Kahoku-gun, Ishikawa, 920-0293, Japan

Phone: +81-76-218-8445

FAX: +81-76-286-1635

E-mail: ushi@kanazawa-med.ac.jp

Total word count (excluding title, abstract, acknowledgment, references, tables, and figure legends): 2466

Number of Tables: 3

Number of Figures: 2

Number of Supplementary Tables: 3

Number of Supplementary Figures: 1

Number of References: 29

ABSTRACT

Importance: The effect of large-scale disasters on bystander cardiopulmonary resuscitation (BCPR) performance is unknown.

Objective: To investigate whether and how the large-scale earthquake and tsunami influenced BCPR performance for out-of-hospital cardiac arrest (OHCA) witnessed by family and friends/colleagues.

Design & Setting: Retrospective analysis of prospectively collected, nationwide, population-based data for OHCA cases.

Participants: From the nationwide OHCA registry recorded between March 11, 2010, and March 10, 2013, we extracted 74,684 family- and friend/colleague-witnessed OHCA cases without prehospital physician involvement.

Exposure: The earthquake and Tsunami that were followed by nuclear pollution and largely affected the social life of citizens for at least 24 weeks.

Main Outcome and Measure: Neurologically favorable outcome after 1 month, 1-month survival and BCPR.

Results: In tsunami-affected prefectures, the 4-week average trend after the day of disaster indicated the impact of the disaster on the BCPR rate during weeks 0–23 (impact phase) in the disaster year 2011, compared with pre- and post-disaster year (2010/2012). Multivariable logistic regression for tsunami-affected prefectures revealed that the BCPR rate during the impact phase in 2011 was significantly lower than that in 2010/2012 (42.5% *vs.* 48.2%;

adjusted odds ratio; 95% confidence interval, 0.82; 0.68–0.99). A lower level of bystander compliance with dispatcher-assisted CPR instructions (62.1% *vs.* 69.5%, 0.72; 0.57–0.92) in the presence of a preserved level of voluntary BCPR performance (23.6% *vs.* 23.8%) was also observed. Both 1-month survival and neurologically favorable outcome rates during the impact phase in 2011 were significantly poorer than those in 2010/2012 (8.5% *vs.* 10.7%, 0.72; 0.52–0.99, 4.0% *vs.* 5.2%, 0.62; 0.38–0.98, respectively).

Conclusion and Relevance: A large-scale disaster with nuclear pollution influences BCPR performance and clinical outcomes of OHCA witnessed by family and friends/colleagues. Basic life-support training leading to voluntary-initiated BCPR might serve as preparedness for disaster and major accidents.

(Word count: 299)

Strengths and limitations of this study

This study focused on alterations in bystander-initiated and dispatcher-instructed BCPR after a large-scale disaster.

Not only before-after comparisons but also differences in trends were analyzed between tsunami-affected and -unaffected prefectures using a large nationwide database.

The catastrophe occurred in the seacoast areas of some of the prefectures, but the analyses were performed after dividing the prefectures.

Bystander-specific data, such as age, sex, and training experience were not included in the database and therefore not available for study.

No research was conducted on whether the bystanders were actually psychologically affected.

Introduction

The Great East Japan Earthquake swept the North-East Pacific coast of the Japanese mainland on March 11, 2011, and an earthquake-generated tsunami destroyed cities, towns, and villages located at the North-East Pacific coast, resulting in the Fukushima Dai-ichi nuclear accident. This disaster forced citizens in afflicted areas to spend a long period as evacuees.[1,2] A considerable number of major aftershocks with and without a tsunami warning (moment magnitude ≥ 6.0) occurred for 24 weeks after the main disaster (Supplemental Figure, upper panel).[3] After evacuation of survivors living in tsunami-affected areas, more than 15,000 people lived temporarily in "shelters" and eventually moved into temporary housing areas, leaving their hometowns. The search for missing people continued for 24 weeks after the disaster. The final number of victims on June 10, 2020 was 22,167, comprising of 19,638 fatalities, which included 3,739 disaster-related deaths and 2,529 missing people (Supplemental Figure, middle panel).[2] Several emergency fire response teams and volunteers provided disaster services in the tsunami-affected prefectures (Supplemental Figure, lower panel). Reconstruction of the destroyed towns and cities with resumption of farming and fishery industries began only around 24 weeks after the disaster.[4] Several aspects of this disaster have been reviewed over the past 10 years following the disaster.[2]

Large-scale disasters or catastrophes may psychologically affect the social behavior of citizens.[5,6] Disasters are known to temporally increase the incidence of cardiovascular events and other acute illnesses that may lead to out-of-hospital cardiac arrest (OHCA).[7-9]

The outcomes of OHCA depend on dispatcher-assisted and bystander-initiated resuscitation efforts and on initial basic life-support (BLS) actions by bystanders who witness OHCA.[10] The Fukushima nuclear pollution disaster and the large-scale pandemic such as coronavirus disease 2019 (COVID-19) may augment the level of general fear of pollution and infection in the population, which might discourage BLS actions[11,12]. However, the impact of large-scale disasters on BLS actions of laypersons is unknown. This study aimed to investigate whether and how the 2011 earthquake influenced the bystander cardiopulmonary resuscitation (BCPR) and outcomes in OHCA cases witnessed by family, friends and colleagues in the prefectures that were most affected by the earthquake.

Methods

Data selection and grouping

From the 381,581 nationwide OHCA cases in the All-Japan Utstein Registry of the Japanese Fire and Disaster Management Agency (FDMA), which holds the Utstein-style information[13], recorded between March 11, 2010 and March 10, 2013, we extracted 74,684 family- and friend/colleague-witnessed OHCA cases with no prehospital physician involvement to minimize the effect of healthcare providers volunteering for and/or being involved in disaster medical support (Figure 1). The study period included of the pre-disaster year 2010 (2010.3.11–2011.3.10), the disaster year 2011 (2011.3.11–2012.3.10), and the post-disaster year 2012 (2012.3.11–2013.3.10). Tsunami-affected prefectures, defined as prefectures in which a tsunami with a maximum height of > 4 meters was observed, included five prefectures located in the North-East Pacific coast of the Japanese mainland: Aomori, Iwate, Miyagi, Fukushima and Ibaraki prefectures.[1] The prefectures other than these five tsunami-affected prefectures were designated as other prefectures.

Outcome measures

The primary outcome of this study was provision of BCPR by a family member or a friend/colleague. The secondary outcomes were a neurologically favorable outcome after 1 month, defined as a cerebral performance category score of 1 (good recovery) or 2 (moderate disability)[14] and 1-month survival.

Data analysis

On the basis of the occurrence of aftershocks, number of evacuees in evacuation centers and resumption of social activities, we determined that 0-23 weeks from March 11, 2011 was the period affected by the disaster. We have defined the same period from 2010 to 2012 as the impact phase.

We analysed the 4-week average trends in the BCPR rate after the day of disaster in the year 2011 and on the same day (11 March) in the pre-disaster year of 2010 and post-disaster year of 2012 in the tsunami-affected and other prefectures. We investigated whether and how the disaster affected the BCPR and outcomes of OHCA in the tsunami-affected prefectures using univariate and multivariable logistic regression analyses. The BCPR rates, 1-month survival rates and neurologically favorable 1-month outcomes were compared between the disaster year (2011) and the pre-/post-disaster years (2010/2012) during the impact and the post-impact phases in tsunami-affected and other prefectures.

Furthermore, to clarify the association of the impact phase with dispatcher-assisted and bystander-initiated resuscitation efforts, we calculated the following three indices related to dispatcher-assisted CPR (DA-CPR) and BCPR in accordance with a previous report[15]: 1) DA-CPR sensitivity for OHCA, which reflects the number of cases for which DA-CPR was attempted divided by the number of cases not receiving voluntary-initiated BCPR without DA-CPR attempt or dispatcher assistance; 2) bystander's compliance to DA-CPR (or the acceptance rate of DA-CPR), which represents the number of cases receiving dispatcher-instructed BCPR following a DA-CPR attempt divided by the number of cases for which DA-CPR was attempted; and 3) the degree of voluntary performance of BCPR (or the rate of bystander-initiated CPR in OHCA patients without DA-CPR), which is the number of cases receiving BCPR initiated on a voluntary basis without DA-CPR attempt or dispatcher assistance divided by the number of cases for which DA-CPR was not attempted.[10.16]

Univariate analyses were performed using the chi-square test or Fisher's exact probability test for nominal variables and the Mann–Whiney *U*-test for continuous variables. Multivariable logistic regression analysis for BCPR provision included the factors, which were well known to be associated with BCPR provision: daytime, weekend, patient sex and age, etiology of OHCA (presumed cardiac or not, exogenous origin), family bystander and DA-CPR instruction. Factors included in multivariable logistic regression analysis for outcomes were daytime, patient sex and age, presumed cardiac etiology, initial rhythm (shockable or not), BCPR provision, family bystander, tracheal intubation and epinephrine administration by paramedics, time interval between witness and emergency call, and time interval between emergency call and emergency medical service (EMS) arrival at patients (EMS response time). All tests were two-tailed, and we considered a probability (P) value < 0.05 to be statistically significant. All statistical analyses were performed using the JMP Pro 15 software (SAS Institute, Cary, NC).

Results

Four-week average trends in BCPR provision after the day of disaster

In other prefectures (the tsunami-not-affected prefectures), the trend of BCPR rate was the same in 2011 (year of disaster) and 2010/2012. The BCPR rate remained at nearly 40% throughout the 3 years, regardless of the impact phase of the disaster (before and after the disaster; Figure 2, lower panel). Furthermore, there were no obvious seasonal variations.

On the other hand, the trends in the BCPR rate in 2011 (disaster year) differed from those of 2010/2012 (pre- and post-disaster years) in the tsunami-affected prefectures (Figure 2, upper panel). In 2010/2012, the BCPR rate remained high (> 50%) during weeks 4–23 (corresponding to the spring and summer seasons) whereas it was low (nearly 40%) during weeks 36–43 (winter season). However, the BCPR rate remained low except for weeks 8–15 after the disaster, and no seasonal variations were observed in 2011. The impact phase coincided with the period during which the differences in the 4-week averages of BCPR between 2011 and 2010/2012 were recognized in the tsunami-affected prefectures.

Differences in the backgrounds and characteristics of OHCA between the disaster year and the pre-/post-disaster years

In the tsunami-affected prefectures, during the impact phase, the incidence of OHCA during weekends and the proportion of cases of presumed cardiac etiology in 2011 were higher than those in 2010/2012, whereas the rate of DA-CPR was lower. As expected, transportation time from the scene to the hospital was prolonged in 2011. During the post-impact phase, there was no significant difference in backgrounds between 2011 and 2010/2012 (Table 1).

In other prefectures, significant differences in some prehospital confounders were observed between 2011 and 2010/2012 during the impact and post-impact phases. However, the differences in these parameters were very small (Supplemental Table 1).

Multivariable regression analyses of the differences in BCPR provision and outcomes between the disaster year and the pre-/post-disaster years

In the tsunami-affected prefectures, the rates of BCPR, 1-month survival and 1-month neurologically favorable outcome in 2011 were significantly lower than those in 2010/2012 during the impact phase. During the post-impact phase, no significant difference in any of these parameters was observed between 2011 and 2010/2012. (Table 2). In other prefectures, significant differences were observed neither during the impact phase nor during the post-impact phase (Supplemental Table 2).

The multivariable regression analysis disclosed that that DA-CPR (with adjusted ORs ranging from 7.07 to 9.27) was a common and major factor associated with BCPR provision, regardless of the phase and prefecture. The major factors associated with a neurologically favorable outcome included shockable initial rhythm and EMS response time. Notably, the adjusted OR (95% confidence interval [CI]) of shockable initial rhythms for neurologically favorable outcome was much higher during the impact phase than during the post-impact phase in tsunami-affected prefectures (12.7 [7.3–20.9] *vs.* 7.1 [4.72–10.8]).

Analysis of indices for dispatcher-assisted and bystander-initiated resuscitation efforts

In tsunami-affected prefectures, DA-CPR sensitivity and bystander's compliance to DA-CPR appeared to be suppressed during the impact phase in 2011, being 55.8% and 62.1%, respectively in 2011, and 60.0% and 69.5%, respectively in 2010/2012. However, the difference between 2011 and 2010/2012 was significant only for bystander's compliance to DA-CPR (Adjusted OR; 95% CI, 0.72; 0.57–0.92). During the post-impact phase, there were no significant differences in these indices between 2011 and 2010/2012. Difference in the performance of BCPR was detected neither during the impact phase nor during the postimpact phase (Table 3).

In other prefectures, none of the three indices differed between 2011 and 2010/2012; neither during the impact phase nor during the post-impact phase (Supplemental Table 3).

Discussion

In disaster mental health, the reactions of the community and the individual are usually divided to four phases (heroic phase, honeymoon phase, disillusionment phase and restoration phase)[17] although the duration of these phase may vary depending on the scale and type of disaster. The impact phase in this study covers the period from heroic phase to disillusionment phase. This relatively long impact phase and the wide area affected by the disaster may contribute to the detection of a significant impact of disaster in this study.

Loss of family members and friends, lack of employment stability, or extensive damage to property, resulting in loss of or a decrease in income are reported as risk factors for the development of disaster-related mental health problems.[18-20] In this study, the BCPR rate in tsunami-affected prefectures temporally increased during the 8–11 weeks after the disaster but remained low thereafter, reflecting a temporal relief in anxiety due to increased provision of supplies and accommodation during the "honeymoon phase" and recognition of depressed economic resilience, repeated aftershocks and escape or avoidance behavior[21] during disillusionment phase.

The BCPR rate varies between countries, but the BCPR rate in Japan in the 3 years from 2010 to 2012 was as high as or higher than that in the European Union and United States. The higher BCPR rate in tsunami-affected prefectures, compared with other prefectures might be due to the higher proportion of citizens having attended the BLS training courses (17.0% in tsunami-affected prefectures and 11.6% in other prefectures in 2008).[22.23] Compared with the patients with OHCA in the other (non-affected) prefectures, those in the tsunami-affected prefectures were subject to relatively higher BCPR rates in the pre- and post-disaster years, particularly during the spring and summer seasons, which is identical to that in the impact phase that we determined. Major industries in the affected areas included fishery, agriculture and food processing managed by corporative unions. The population, particularly the elderly, typically endures a rugged winter at home, and their social activities diminish at the end of autumn and over the winter. Meanwhile, during the spring and summer, citizens including the elderly cooperate in agricultural work and preparation of social events, including festivals and outdoor events.[24] Increased collaborative activities of citizens, including the elderly, in these seasons and accommodativeness as a general personality trait of the citizens might be one of the reasons for this seasonal variation in BCPR rate because OHCA cases in these seasons are frequently managed by many bystanders including those with training experience.

Surveys on citizens and EMS personnel who survived the disaster in tsunami-affected prefectures reported that more than half of them lost their family and friends/colleagues.[25] People who died during the disaster were mostly the elderly (54.40%), suggesting that the proportion of trained bystanders was not affected by the disaster[26]. Thus, decreased rates of BCPR and DA-CPR may be attributed to the decreased collaborative social activities and psychological reactions of dispatchers and bystanders, which may interfere with communication between bystanders and dispatchers.

The 2011 earthquake and the earthquake-associated tsunami were followed by a nuclear accident in the Fukushima prefecture. People who had a false understanding of radiation were afraid to interact with evacuees and avoided contact. For these reasons, it is highly possible that nuclear pollution may interfere with bystander-initiated CPR provision due to augmented fear of nuclear pollution during CPR, particularly of refugees from the polluted area.[27] Recent studies on the COVID-19 pandemic on BCPR support this assumption.[12]

It might be difficult to prevent the BCPR and certain outcomes from deteriorating during the impact phase. The analysis of the three indices related to DA-CPR and BCPR showed that the level of voluntary performance of BCPR was relatively preserved during the impact phase in tsunami-affected prefectures. Multivariable regression analysis showed that shockable initial rhythm was a major factor associated with neurologically favorable outcomes. This suggests that BLS training including automated external defibrillator (AED) use and its supply might function as preparedness for disaster and major accidents.

Limitation

The present study has several strengths. Firstly, this study focused on alterations in bystander-initiated and dispatcher-instructed BCPR after a large-scale disaster. Secondly, not only before-after comparisons but also differences in trends were analysed between tsunami-affected and -unaffected prefectures using a large nationwide dataset. However, this study also has several limitations. First, although the catastrophe occurred in the coastal areas of some of the prefectures, the analyses were performed after dividing the prefectures. In tsunami-affected prefectures, no major urban areas were located in the coastal area, and differences in BCPR intervention between urban and rural areas[28] were excluded in this study. Second, bystander-specific data, such as age, sex and training experience were not included in the database and therefore not available for study. Third, no researches were conducted on whether the bystanders were actually psychologically affected. Therefore, these factors potentially associated with BCPR quality might affect the quality of the study results.[29] Fourth, no comparative analysis was performed with the results of other disasters. Fifth, as with other observational studies, the validity of data is another potential limitation.

Conclusions

A large-scale disaster may influence bystander-initiated CPR and outcomes of OHCA witnessed by family/friends/colleagues. BLS training might serve as preparedness for disaster and major accidents.

Acknowledgments

We thank the EMS personnel and FDMA in Japan for their cooperation in collecting and managing the All-Japan Utstein Registry data. TU and KT equally contributed to this article as first authors.

Article information

Corresponding Author: Tomoyuki Ushimoto, MD, PhD, Department of Emergency Medicine, Kanazawa Medical University, 1-1 Daigaku, Uchinada-machi, Kahoku-gun, Ishikawa 920-0293, Japan

Contributions: The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

TU and KT had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. TU and KT equally contributed to this article as first authors.

Study concept and design: TU and HI.

Acquisition, analysis, and interpretation of data: All authors.

Drafting of the manuscript: AY, HI, KT and TU.

Clinical revision of the manuscript for important intellectual content: TU, HI, KT and YW.

Statistical analysis: TU, KT, and HI.

Obtained funding: None.

Administrative, technical, or material support: HI and YW.

Study supervision: HI and YW.

grant on behalf of all authors, a worldwide licence to the Publishers and its licensees in perpetuity, in all forms, formats and media (whether known now or created in the future), to i) publish, reproduce, distribute, display, and store the Contribution, ii) translate the Contribution into other languages, create adaptations, reprints, include within collections and create summaries, extracts and/or, abstracts of the Contribution, iii) create any other derivative work(s) based on the Contribution, iv) to exploit all subsidiary rights in the Contribution, v) the inclusion of electronic links from the Contribution to third party material wherever it may be located; and, vi) licence any third party to do any or all of the above.

Conflict of Interest Disclosures: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: This study was approved by the institutional review board of the Ishikawa Medical Control Council and conducted by the study group comprising of members of the Ishikawa Medical Control Council and their collaborators. Patient consent was not required for use of the secondary data.

Transparency: TU affirmed that the manuscript is an honest, accurate, and transparent account of the study.

Funding: None.

Data sharing: No additional data available.

Patient and Public involvement: Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our study.

Additional information: Some references used in this article are available online and cited as embedded hyperlinks.

References

1. Department of International Affairs, Japan Science and Technology Agency. The Great East Japan Earthquake Information from Official Websites, 2011 (Accessed 23 March 2021, at https://www.jst.go.jp/pr/pdf/great_east_japan_earthquake.pdf).

2. Fire and Disaster Management Agency (Japan). Great East Japan Earthquake (in Japanese) (Accessed 23 March 2021, at https://www.fdma.go.jp/disaster/higashinihon/).

3. Ozdemir O, Boysan M, Guzel Ozdemir P, Yilmaz E. Relationships between posttraumatic stress disorder (PTSD), dissociation, quality of life, hopelessness, and suicidal ideation among earthquake survivors. Psychiatry Res 2015; 228: 598-605. doi: 10.1016/j.psychres.2015.05.045.

4. Makwana N. Disaster and its impact on mental health: A narrative review. J Family Med Prim Care 2019; 8: 3090-3095. doi: 10.4103/jfmpc.jfmpc_893_19.

5. Leor J, Poole WK, Kloner RA. Sudden cardiac death triggered by an earthquake. N Engl J Med 1996; 34: 413-419.

6. Ogawa K, Tsuji I, Shiono K, Hisamichi S. Increased acute myocardial infarction mortality following the 1995 Great Hanshin-Awaji earthquake in Japan. Int J Epidemiol 2002; 29: 449-455.

7. Sokejima S, Nakatani Y, Kario K, Kayaba K, Minowa M, Kagamimori S. Seismic intensity and risk of cerebrovascular stroke: 1995 Hanshin-Awaji earthquake. Prehosp Disaster Med 2004; 19: 297-306.

8. Yamashita A, Maeda T, Myojo Y, Wato Y, Ohta K, Inaba H. Temporal variations in dispatcher-assisted and bystander-initiated resuscitation efforts. Am J Emerg Med 2018; 36: 2203-2210. doi: 10.1016/j.ajem.2018.03.080.

9. Savastano S, Vanni V. Cardiopulmonary resuscitation in real life: The most frequent fears of lay rescuers. Resuscitation 2011; 82: 568-571. doi:10.1016/j.resuscitation.2010.10.010

10. Pranata R, Lim MA, Yonas E, Siswanto BB, Meyer M. Out-of-hospital cardiac arrest

prognosis during the COVID-19 pandemic. Intern Emerg Med 2020; (0123456789): 7-9. doi:10.1007/s11739-020-02428-7.

11. Japan Meteorological Agency. The 2011 Great East Japan Earthquake: Number of aftershock (in Japanese) (Accessed 23 March 2021, at http://www.data.jma.go.jp/svd/eqev/data/2011_03_11_tohoku/aftershock/).

12. Japan National Council of Social Welfare. Number of disaster volunteers (in Japanese), (Accessed 23 March 2021, at https://www.saigaivc.com/new/?tag=2011%E6%9D%B1%E6%97%A5%E6%9C%AC%E5%A4%A7%E9%9C%87%E7%81%BD).

13. Reconstruction Agency (Japan). Recovery and Reconstruction from the Great East Japan Earthquake, 2012 (in Japanese) (Accessed 23 March 2021, at https://www.reconstruction.go.jp/topics/20130104_higashinippondaishinsai_fukkoh.pdf).

14. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International liaison Committee on resuscitation. Circulation 2004; 110: 3385–97.

15. Portal Site of Official Statistics of Japan (e-Stat). 2010 Population Census (Accessed 23 March 2021, at https://www.e-stat.go.jp/en/stat-search/files?page=1&toukei=00200521&tstat=000001039448).

16. Portal Site of Official Statistics of Japan website. 2010 Population Census (Accessed 23 March 2021, at http://www.stat.go.jp/english/data/kokusei/2010/summary.html).

17. Math SB, Nirmala MC, Moirangthem S, Kumar NC. Disaster Management: Mental Health Perspective. Indian J Psychol Med 2015; 37: 261-71. doi: 10.4103/0253-7176.162915.

18. Norris FH, Friedman MJ, Watson PJ, Byrne CM, Diaz E, Kaniasty K. 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981-2001. Psychiatry 2002; 65: 207-39.

19. Başoğlu M, Kiliç C, Salcioğlu E, Livanou M. Prevalence of posttraumatic stress disorder and comorbid depression in earthquake survivors in Turkey: an epidemiological study. J Trauma Stress 2004; 17: 133-41.

20. van Griensven F, Chakkraband ML, Thienkrua W, et al. Mental health problems among adults in tsunami-affected areas in southern Thailand. JAMA 2006; 296: 537-48.

21. Avoidance behavior. (n.d.) Miller-Keane Encyclopedia and Dictionary of Medicine, Nursing, and Allied Health, Seventh Edition. (2003). (Retrieved 23 March 2021 from https://medical-dictionary.thefreedictionary.com/Avoidance+behavior).

22. Nishi T, Kamikura T, Funada A, Myojo Y, Ishida T, Inaba H. Are regional variations in activity of dispatcher-assisted cardiopulmonary resuscitation associated with out of-hospital cardiac arrests outcomes? A nation-wide population-based cohort study. Resuscitation 2016; 98: 27–34. doi: 10.1016/j.resuscitation.2015.10.004.

23. Fire and Disaster Management Agency (Japan). Rescue operations and first-aid, 2009 (in Japanese) (Accessed 23 March 2021, at https://www.fdma.go.jp/publication/rescue/items/03_genkyou.pdf).

24. Maeda T, Yamashita A, Myojo Y, Wato Y, Inaba H. Augmented survival of out-of-hospital cardiac arrest victims with the use of mobile phones for emergency communication under the DA-CPR protocol getting information from callers beside the victim. Resuscitation 2016; 107: 80-87. doi:10.1016/j.resuscitation.2016.08.010

25. Portal Site of Official Statistics of Japan website. Population Estimates, Annual Report 2008 (Accessed 23 March 2021, at https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001&cycle=7&year=20080&month=0&tclass1=000001011679&result_back=1).

26. Ministry of Health, Labor and Welfare (Japan). Overview of 2011 vital statistics, death situation due to the Great East Japan Earthquake from the viewpoint of vital statistics. (Accessed 23 March 2021, at

https://www.mhlw.go.jp/toukei/saikin/hw/jinkou/kakutei11/dl/14_x34.pdf).

27. Maeda M, Oe M. Mental Health Consequences and Social Issues After the Fukushima Disaster. Asia Pac J Public Health 2017; 29: 36-46. doi:10.1177/1010539516689695.

28. Mathiesen W, Bjørshol C, Kvaløy J, Søreide E. Effects of modifiable prehospital factors on survival after out-of-hospital cardiac arrest in rural versus urban areas. Crit Care 2018; 22: 99. doi:10.1186/s13054-018-2017-x.

29. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without instruction. Resuscitation 2014; 85: 492-8. doi:10.1016/j.resuscitation.2013.12.019.

Legends to figures

Figure 1: Data selection and subgroup extraction

OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service.

Figure 2: Four-week average trends of bystander cardiopulmonary resuscitation in tsunami-affected prefectures and other prefectures

BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11.

Supplemental Figure: Analysis of the disaster status and social responses

Mw, Moment magnitude.

Table 1 Background, characteristics, and time factors of family- and friend/colleague-witnessed out-of-hospital cardiac arrest cases in tsunami-affected prefectures

Background, characteristics, and time factors	Impact phase		Unadjusted OR (95% CI) [a] or P-value	Post-impact phase		Unadjusted OR (95% CI) [a] or P-value
	2011 (N = 882)	2010/2012 (N = 1,565)		2011 (N = 1,179)	2010/2012 (N = 2,454)	
Family-witnessed patients, No. (%)	783 (88.8)	1,404 89.7)	0.91 (0.70–1.18)	1,074 (91.1)	2,219 (90.4)	1.08 (0.85–1.38)
Daytime (7:00 a.m.–7:00 p.m.), No. (%)	520 (59.0)	950 (60.7)	0.93 (0.79–1.10)	682 (57.9)	1,485 (60.5)	0.90 (0.79–1.03)
Weekend, No. (%)	141 (16.0)	192 (12.3)	**1.36 (1.08–1.72)**	146 (12.4)	338 (13.8)	0.89 (0.72–1.09)
Age, median (IQR), y	78 (65–84)	76 (63–84)	0.12	77 (66–84)	78 (67–85)	0.17
Male patient, No. (%)	598 (67.8)	1,002 (64.0)	1.18 (1.00–1.41)	734 (62.3)	1,525 (62.1)	1.01 (0.87–1.16)
Presumed cardiac etiology, No. (%)	554 (62.8)	877 (56.0)	**1.33 (1.12–1.57)**	725 (61.5)	1,443 (58.8)	1.12 (0.97–1.29)
Exogenous origin [b], No. (%)	102 (11.6)	206 (13.2)	0.86 (0.67–1.11)	118 (10.0)	259 (10.6)	0.94 (0.75–1.19)
Shockable initial rhythm, No. (%)	162 (18.4)	271 (17.3)	1.07 (0.87–1.33)	185 (15.7)	345 (14.1)	1.14 (0.94–1.38)
Dispatcher-assisted CPR, No. (%)	433 (49.1)	835 (53.4)	**0.84 (0.72–0.99)**	598 (50.7)	1,240 (50.5)	1.01 (0.88–1.16)
Defibrillation by bystanders with an AED, No. (%)	4 (0.5)	9 (0.6)	0.79 (0.24–2.58)	11 (0.9)	12 (0.6)	1.65 (0.73–3.75)
Epinephrine administration by paramedics, No. (%)	153 (17.4)	256 (16.4)	1.07 (0.86–1.34)	231 (19.6)	448 (19.7)	1.00 (0.84–1.19)
Tracheal intubation by paramedics, No. (%)	78(8.8)	161 (10.3)	0.85 (0.64–1.12)	103 (8.7)	251 (10.2)	0.84 (0.66–1.07)
Time intervals, median (IQR), min						
Witness-to-emergency call	2 (0–5)	2 (0–5)	0.71	2 (0–5)	2 (0–5)	0.49
EMS response time [C]	8 (7–11)	9 (7–11)	0.45	9 (7–11)	9 (7–12)	0.11

EMS arrival at patient-to-arrival at the hospital	21 (16–28)	20 (15–27)	**< 0.05**	22 (16–29)	22 (16–29)	0.74

OR, odds ratio; CI, confidence interval; IQR, interquartile range; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; EMS, emergency medical service; impact phase, 0-23 weeks from March 11;

post-impact phase, from 24 weeks after March 11 until March 11 of the following year

a) 2010/2012 as a reference

b) Asphyxia, submersion, hypothermia, poisoning, and trauma

c) Time interval between emergency call and EMS arrival at patient

Table 2 Phasic comparisons of bystander cardiopulmonary resuscitation and outcomes between 2011 and 2010/2012 in tsunami-affected prefectures

BCPR and outcomes	Impact phase		Adjusted OR (95% CI) with 2010/2012 as a reference	Post-impact phase		Adjusted OR (95% CI) with 2010/2012 as a reference
	2011 (N = 882)	2010/2012 (N = 1,565)		2011 (N = 1,179)	2010/2012 (N = 2,454)	
BCPR rate, No. (%)	375 (42.5)	754 (48.2)	**0.82 (0.68–0.99)**	510 (43.3)	1,068 (43.5)	0.99 (0.84–1.16)
1-month survival, No. (%)	75 (8.5)	168 (10.7)	**0.72 (0.52–0.99)**	103 (8.7)	200 (8.2)	1.02 (0.78–1.33)
Neurologically favorable outcome, No. (%)	35 (4.0)	82 (5.2)	**0.62 (0.38–0.98)**	48 (4.1)	107 (4.4)	0.89 (0.61–1.29)

BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11; post-impact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

Table 3 Phasic comparisons of indices for dispatcher-assisted and bystander-initiated resuscitation efforts between 2011 and 2010/2012 in tsunami-affected prefectures

Indices related to DA-CPR and BCPR	Impact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference	Post-impact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference
	2011	2010/2012		2011	2010/2012	
DA-CPR sensitivity, No./total (%)	433/776 (55.8)	835/1,391 (60.0)	0.84 (0.70–1.00)	598/1,062 (56.3)	1,240/2,224 (55.8)	1.02 (0.88–1.19)
Bystander's compliance to DA-CPR, No./total (%)	**269/433 (62.1)**	**255/835 (69.5)**	**0.72 (0.57–0.92)**	393/598 (65.7)	838/1,240 (67.6)	0.92 (0.75–1.13)
Voluntary performance of BCPR, No./total (%)	106/449 (23.6)	174/730 (23.8)	0.99 (0.72–1.07)	117/581 (20.1)	230/1,214 (19.0)	1.08 (0.84–1.39)

DA-CPR, dispatcher-assisted cardiopulmonary resuscitation; BCPR, bystander cardiopulmonary resuscitation;
impact phase, 0-23 weeks from March 11;post-impact phase, from 24 weeks after March 11 until March 11 of the following year;
OR, odds ratio; CI, confidence interval.

Supplemental Table 1 Background, characteristics, and time factors of family- and friend/colleague-witnessed out-of-hospital cardiac arrest cases in non-affected prefectures

Background, characteristics, and time factors	Impact phase		Unadjusted OR (95% CI) [a] or P-value	Post-impact phase		Unadjusted OR (95% CI) [a] or P-value
	2011 (N = 9,696)	2010/2012 (N = 17,985)		2011 (N = 14,024)	2010/2012 (N = 26,899)	
Family-witnessed patients, No. (%)	8,771 (90.5)	16,211 (90.1)	1.04 (0.95–1.13)	12,679 (90.4)	24,452 (90.9)	0.94 (0.88–1.01)
Daytime (7:00 a.m.–7:00 p.m.), No. (%)	5,741 (59.2)	10,653 (59.2)	1.00 (0.95–1.05)	8,285 (59.1)	16,124 (59.9)	0.97 (0.93–1.01)
Weekend, No. (%)	1,362 (14.1)	2,424 (13.5)	1.05 (0.98–1.13)	1,971 (14.1)	3,659 (13.6)	1.04 (0.98–1.10)
Age, median (IQR), y	77 (66–85)	77 (66–85)	0.57	77 (66–85)	78 (67–85)	0.05
Male patient, No. (%)	6,113 (63.1)	11,429 (63.6)	0.98 (0.93–1.03)	8,846 (63.1)	16,795 (62.4)	1.03 (0.99–1.07)
Presumed cardiac etiology, No. (%)	5,661 (58.4)	10,483 (58.3)	1.00 (0.96–1.06)	8,220 (58.6)	16,085 (59.8)	**0.95 (0.91–0.99)**
Exogenous origin [b], No. (%)	1,232 (12.7)	2,202 (12.2)	1.04 (0.97–1.12)	1,709 (12.2)	2,845 (10.6)	**1.17 (1.10–1.25)**
Shockable initial rhythm, No. (%)	1,399 (14.4)	2,598 (14.5)	1.00 (0.93–1.07)	1,979 (14.1)	3,676 (13.7)	1.04 (0.98–1.10)
Dispatcher-assisted CPR, No. (%)	4,882 (50.4)	8,833 (49.1)	1.05 (1.00–1.10)	7,139 (50.9)	13,640 (50.7)	1.01 (0.97–1.05)
Defibrillation by bystanders with an AED, No. (%)	67 (0.7)	145 (0.8)	0.60 (0.64–1.15)	101 (0.7)	197 (0.8)	0.91 (0.72–1.16)
Epinephrine administration by paramedics, No. (%)	2,097 (21.6)	3,891 (21.6)	1.00 (0.94–1.06)	3,084 (22.0)	6,106 (23.5)	**0.92 (0.88–0.97)**
Tracheal intubation by paramedics, No. (%)	845 (8.7)	1,697 (9.4)	**0.92 (0.84–0.99)**	1,246 (8.9)	2,500 (9.3)	0.95 (0.89–1.02)
Time intervals, median (IQR), min						
Witness-to-emergency call	2 (0–5)	2 (0–5)	**<0.005**	2 (0–5)	2 (0–5)	0.24

EMS response time [c]	8 (7–11)	8 (7–10)	0.10	8 (7–11)	8 (7–11)	0.86
Arrival at the patient-to-arrival at the hospital	23 (18–30)	23 (18–30)	0.08	23 (18–30)	24 (18–31)	**<0.01**

IQR, interquartile range; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; EMS, emergency medical service; impact phase, 0-23 weeks from March 11; post-impact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

a) 2010/2012 as a reference

b) Asphyxia, submersion, hypothermia, poisoning, and trauma

c) Time interval between emergency call and EMS arrival at patient

Supplemental Table 2 Phasic comparisons of bystander cardiopulmonary resuscitation and outcomes between 2011 and 2010/2012 in non-affected prefectures

BCPR and outcomes	Impact phase		Adjusted OR (95% CI) with 2010/2012 as a reference	Post-impact phase		Adjusted OR (95% CI) with 2010/2012 as a reference
	2011 (N = 9,696)	2010/2012 (N = 17,985)		2011 (N = 14,024)	2010/2012 (N = 26,899)	
BCPR rate, No. (%)	3,907 (40.3)	7,263 (40.4)	0.96 (0.91–1.02)	5,801 (41.4)	11,059 (41.1)	1.01 (0.96–1.05)
1-month survival, No. (%)	805 (8.3)	1,509 (8.4)	1.00 (0.91–1.10)	1,146 (8.2)	2,120 (7.9)	1.02 (0.94–1.10)
Neurologically favorable outcome, No. (%)	413 (4.3)	735 (4.1)	1.07 (0.93–1.22)	557 (4.0)	1,056 (3.9)	1.01 (0.90–1.13)

BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11; post-impact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

Supplemental Table 3 Phasic comparisons of indices for dispatcher-assisted and bystander-initiated resuscitation efforts between 2011 and 2010/2012 in non-affected prefectures

Indices related to DA-CPR and BCPR	Impact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference	Post-impact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference
	2011	2010/2012		2011	2010/2012	
DA-CPR sensitivity, No./total (%)	4,882/8,834 (55.3)	8,833/16,350 (54.0)	1.05 (0.99–1.11)	7,139/12,788 (55.8)	13,640/24,565 (55.5)	1.05 (0.99–1.11)
Bystander's compliance to DA-CPR, No./total (%)	3,041/4,882 (62.3)	5,628/8,833 (63.7)	0.94 (0.88–1.01)	8,725/13,640 (63.9)	8,725/13,640 (64.0)	1.00 (0.94–1.06)
Voluntary performance of BCPR, No./total (%)	862/4,814 (17.9)	1,635/9,152 (17.9)	1.00 (0.92–1.10)	1,236/6,885 (18.0)	2,334/13,259 (17.6)	1.02 (0.95–1.11)

DA-CPR, dispatcher-assisted cardiopulmonary resuscitation; BCPR, bystander cardiopulmonary resuscitation;
impact phase, 0-23 weeks from March 11; post-impact phase, from 24 weeks after March 11 until March 11 of the following year;
OR, odds ratio; CI, confidence interval.

Figure 1

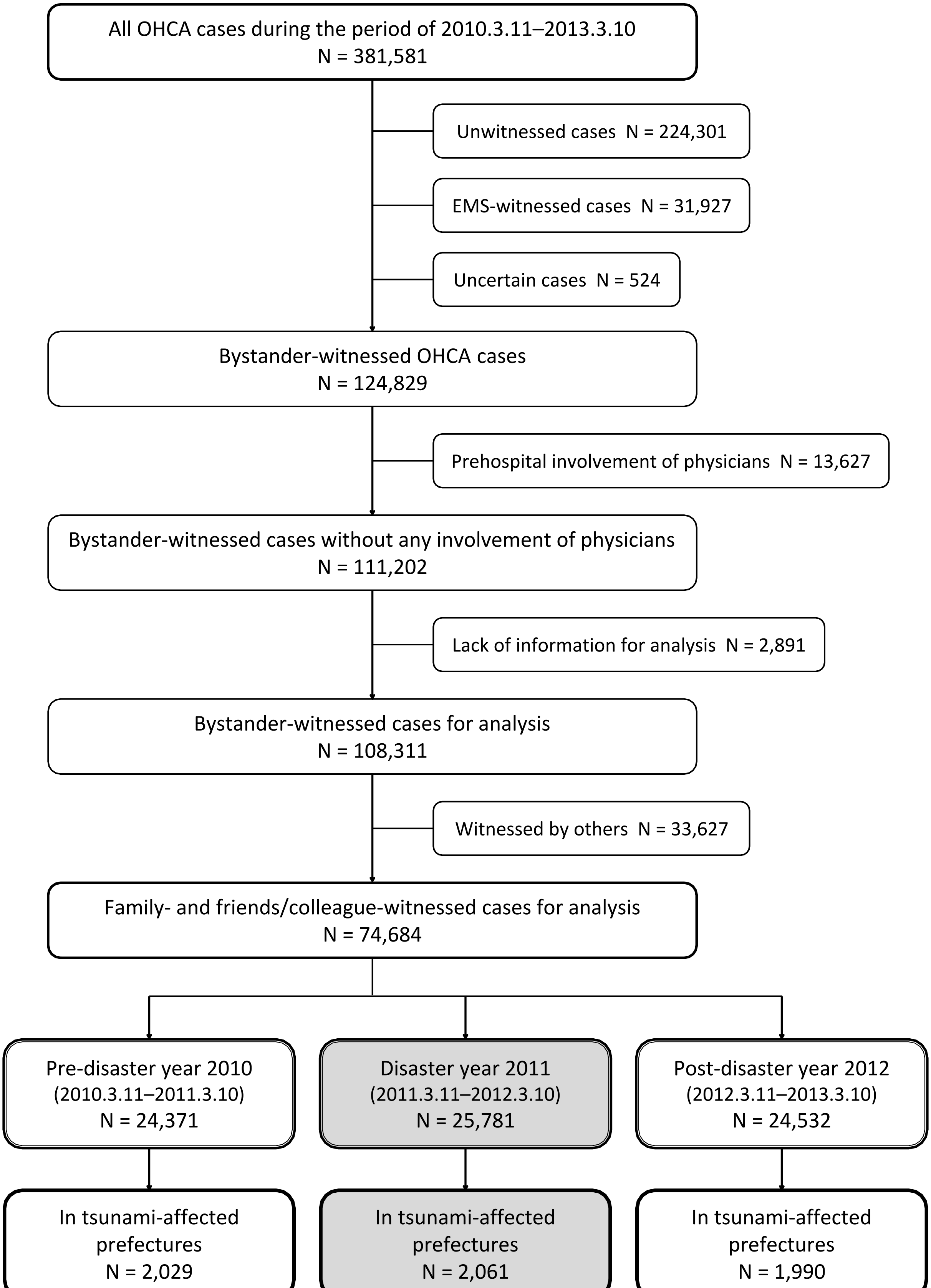
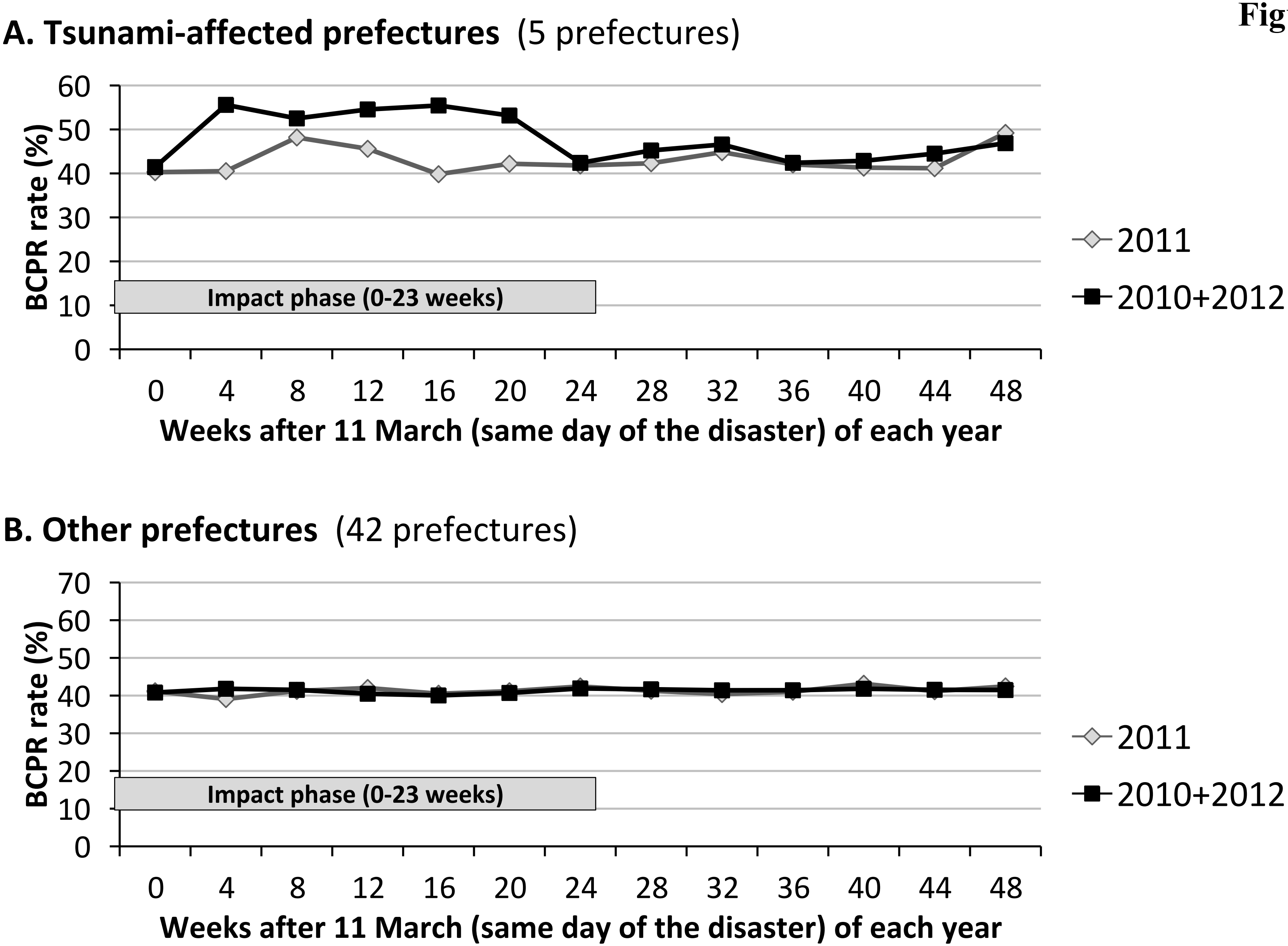
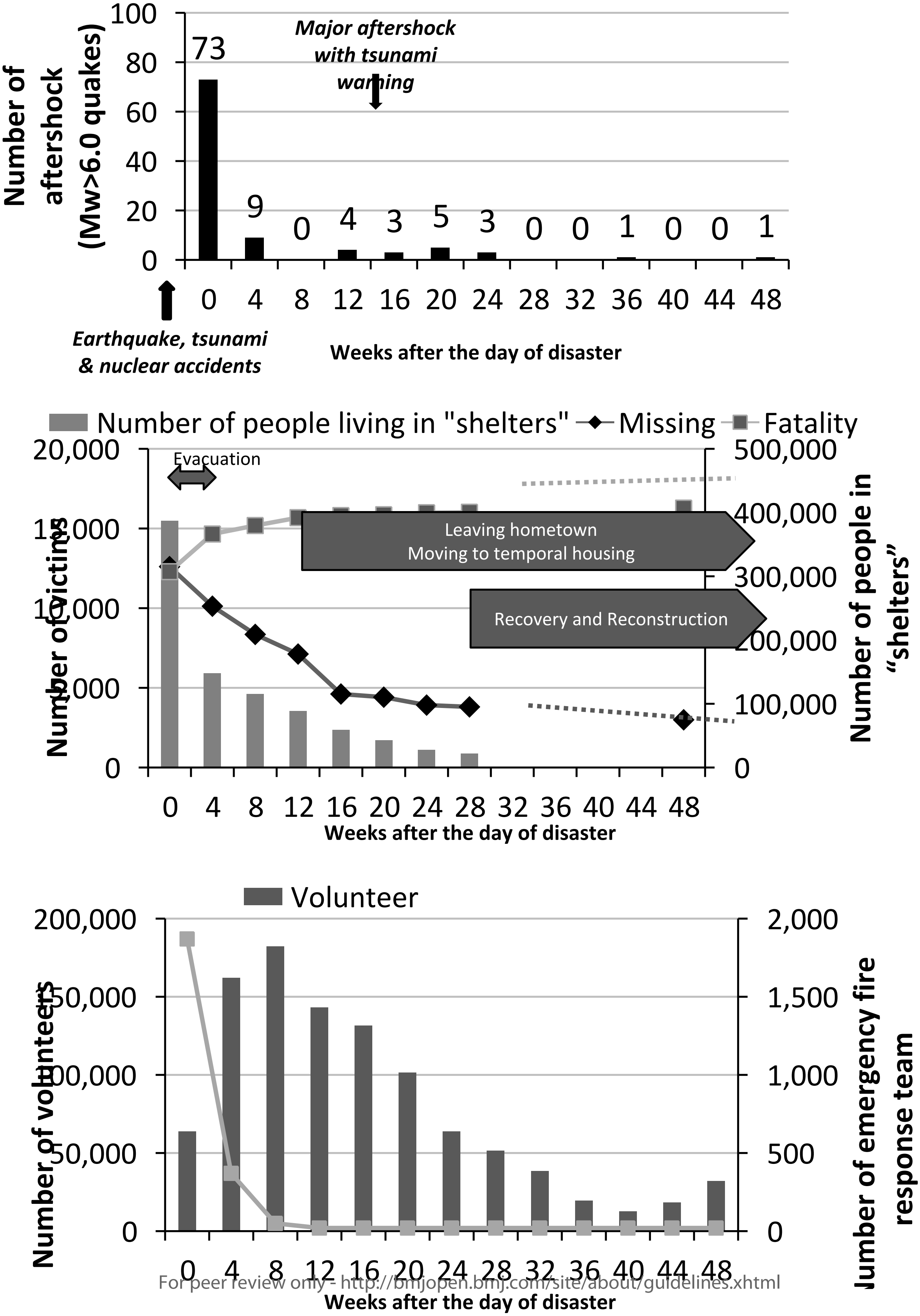

All OHCA cases during the period of 2010.3.11–2013.3.10
N = 381,581
Unwitnessed cases N = 224,301
EMS-witnessed cases N = 31,927
Uncertain cases N = 524
Bystander-witnessed OHCA cases
N = 124,829
Prehospital involvement of physicians N = 13,627
Bystander-witnessed cases without any involvement of physicians
N = 111,202
Lack of information for analysis N = 2,891
Bystander-witnessed cases for analysis
N = 108,311
Witnessed by others N = 33,627
Family- and friends/colleague-witnessed cases for analysis
N = 74,684
Pre-disaster year 2010
(2010.3.11–2011.3.10)
N = 24,371
Disaster year 2011
(2011.3.11–2012.3.10)
N = 25,781
Post-disaster year 2012
(2012.3.11–2013.3.10)
N = 24,532
In tsunami-affected prefectures
N = 2,029
In tsunami-affected prefectures
N = 2,061
In tsunami-affected prefectures
N = 1,990

Figure 2


A. Tsunami-affected prefectures (5 prefectures)
BCPR rate (%)
60
50
40
30
20
10
0
Impact phase (0-23 weeks)
0
4
8
12
16
20
24
28
32
36
40
44
48
Weeks after 11 March (same day of the disaster) of each year
2011
2010+2012
B. Other prefectures (42 prefectures)
BCPR rate (%)
70
60
50
40
30
20
10
0
Impact phase (0-23 weeks)
0
4
8
12
16
20
24
28
32
36
40
44
48
Weeks after 11 March (same day of the disaster) of each year
2011
2010+2012

Supplemental Figure.



Effect of large-scale disasters on bystander-initiated cardiopulmonary resuscitation in family-, friend-, and colleague-witnessed out-of-hospital cardiac arrest: a retrospective analysis of prospectively collected, nationwide, population-based data

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-055640.R1
Article Type:	Original research
Date Submitted by the Author:	04-Jan-2022

Complete List of Authors:	Ushimoto, Tomoyuki; Kanazawa Medical University, Emergency Medicine Takada, Kohei; Kanazawa University Graduate School of Medical Sciences, Department of Circulatory Emergency and Resuscitation Science Yamashita, Akira; Kanazawa University Graduate School of Medical Sciences, Department of Circulatory Emergency and Resuscitation Science; Noto General Hospital, Department of Cardiology Morita, Hideki; Kanazawa Medical University, Department of Emergency Medicine Wato, Yukihiro; Kanazawa Medical University, Emergency medicine Inaba, Hideo; Kanazawa Medical University, Emergency Medicine; Kanazawa Medical University, Department of Emergency Medicine

Primary Subject Heading:	Emergency medicine
Secondary Subject Heading:	Emergency medicine, Medical education and training, Mental health, Public health
Keywords:	ACCIDENT & EMERGENCY MEDICINE, EDUCATION & TRAINING (see Medical Education & Training), MEDICAL EDUCATION & TRAINING, PUBLIC HEALTH

1

Effect of large-scale disasters on bystander-initiated cardiopulmonary resuscitation in family-, friend-, and colleague-witnessed out-of-hospital cardiac arrest: a retrospective analysis of prospectively collected, nationwide, population-based data

Tomoyuki Ushimoto, MD, PhD[1] (0000-0002-9060-9391), Kohei Takada, BA[2], Akira Yamashita, MD, PhD[2,3], Hideki Morita, MD[1], Yukihiro Wato, MD, PhD[1], Hideo Inaba, MD, PhD[1,4]

[1]Department of Emergency Medicine, Kanazawa Medical University, Uchinada, Japan

[2]Department of Circulatory Emergency and Resuscitation Science, Kanazawa University Graduate School of Medicine, Kanazawa, Japan

[3]Department of Cardiology, Noto General Hospital, Nanao, Japan

[4]Kanazawa University, Kanazawa, Japan

E-mail addresses:

TU; ushi@kanazawa-med.ac.jp, KT; tatatakakakadadada612@yahoo.co.jp, AY; yamashita@noto-hospital.jp, HM; moririn@p2223.nsk.ne.jp, YW; allstar@kanazawa.med.ac.jp, HI; mauriakoi@ybb.ne.jp

*Address for correspondence:

Tomoyuki Ushimoto, MD, PhD, Assistant Professor of Emergency Medicine, Kanazawa Medical University

1-1 Daigaku, Uchinada-machi, Kahoku-gun, Ishikawa, 920-0293, Japan

Phone: +81-76-218-8445

FAX: +81-76-286-1635

E-mail: ushi@kanazawa-med.ac.jp

Total word count (excluding title, abstract, acknowledgment, references, tables, and figure legends): 2831

Number of Tables: 3

Number of Figures: 2

Number of Supplementary Tables: 3

Number of Supplementary Figures: 1

Number of References: 35

ABSTRACT

Importance: The effect of large-scale disasters on bystander cardiopulmonary resuscitation (BCPR) performance is unknown.

Objective: To investigate whether and how large-scale earthquake and tsunami as well as subsequent nuclear pollution influenced BCPR performance for out-of-hospital cardiac arrest (OHCA) witnessed by family and friends/colleagues.

Design & Setting: Retrospective analysis of prospectively collected, nationwide, population-based data for OHCA cases.

Participants: From the nationwide OHCA registry recorded between March 11, 2010, and March 10, 2013, we extracted 74,684 family- and friend/colleague-witnessed OHCA cases without prehospital physician involvement.

Exposure: Earthquake and tsunamis that were followed by nuclear pollution and largely affected the social life of citizens for at least 24 weeks.

Main Outcome and Measure: Neurologically favorable outcome after 1 month, 1-month survival, and BCPR.

Methods: We analyzed the 4-week average trend of BCPR rates in the years affected and before and after the disaster. We used univariate and multivariate logistic regression analyses to investigate whether these disasters affected BCPR and OHCA results.

Results: Multivariable logistic regression for tsunami-affected prefectures revealed that the BCPR rate during the impact phase in 2011 was significantly lower than that in 2010/2012

(42.5% *vs.* 48.2%; adjusted odds ratio; 95% confidence interval, 0.82; 0.68–0.99). A lower level of bystander compliance with dispatcher-assisted CPR instructions (62.1% *vs.* 69.5%, 0.72; 0.57–0.92) in the presence of a preserved level of voluntary BCPR performance (23.6% *vs.* 23.8%) was also observed. Both 1-month survival and neurologically favorable outcome rates during the impact phase in 2011 were significantly poorer than those in 2010/2012 (8.5% *vs.* 10.7%, 0.72; 0.52–0.99, 4.0% *vs.* 5.2%, 0.62; 0.38–0.98, respectively).

Conclusion and Relevance: A large-scale disaster with nuclear pollution influences BCPR performance and clinical outcomes of OHCA witnessed by family and friends/colleagues. Basic life-support training leading to voluntary-initiated BCPR might serve as preparedness for disaster and major accidents.

(Word count: 299)

Strengths and limitations of this study

We studied the effects of large-scale disasters such as the Great East Japan Earthquake on the performance of bystander cardiopulmonary resuscitation (BCPR).

Analysis was performed using the 381,581 national OHCA cases in the All-Japan Utstein Registry of the Fire and Disaster Management Agency (FDMA) of Japan recorded between March 11, 2010 and March 10, 2013.

The primary outcome was the provision of BCPR by family or friends / colleagues, and the secondary outcomes were 1-month survival and neurologically favorable outcome after 1 month.

What is already known on this topic

Large-scale disasters or catastrophes may psychologically affect the social behavior of citizens for a long duration.

Disasters are known to temporarily increase the incidence of cardiovascular events and other acute illnesses that may lead to out-of-hospital cardiac arrest (OHCA).

The outcomes of OHCA depend on dispatcher-assisted and bystander-initiated resuscitation efforts and on initial basic life-support (BLS) actions by bystanders who witness OHCA.

What this study adds

A large-scale disaster with nuclear pollution influences the BCPR performance and clinical outcomes of OHCA witnessed by family and friends/colleagues.

BLS training that leads to voluntary-initiated BCPR might serve as preparedness for disaster and major accidents.

Introduction

The Great East Japan Earthquake swept the North-East Pacific coast of the Japanese mainland on March 11, 2011, and an earthquake-generated tsunami destroyed cities, towns, and villages located at the North-East Pacific coast, resulting in the Fukushima Dai-ichi nuclear accident. This disaster forced citizens in afflicted areas to spend a long period as evacuees.[1,2] A considerable number of major aftershocks with and without a tsunami warning (moment magnitude ≥ 6.0) occurred for 24 weeks after the main disaster (Supplemental Figure, upper panel).[3] After evacuation of survivors living in tsunami-affected areas, more than 15,000 people lived temporarily in "shelters" and eventually moved into temporary housing areas, leaving their hometowns. The search for missing people continued for 24 weeks after the disaster. Based on a survey conducted on June 10, 2020, the final number of victims was 22,167, comprising 19,638 fatalities, which included 3,739 disaster-related deaths and 2,529 missing people (Supplemental Figure, middle panel).[2] Several emergency fire response teams and volunteers provided disaster services in the tsunami-affected prefectures (Supplemental Figure, lower panel). Reconstruction of the destroyed towns and cities with resumption of farming and fishery industries began only around 24 weeks after the disaster.[4] Several aspects of this disaster have been reviewed over the past 10 years following the disaster.[2]

Large-scale disasters or catastrophes may psychologically affect the social behavior of citizens.[5,6] Disasters are known to temporally increase the incidence of cardiovascular events and other acute illnesses that may lead to out-of-hospital cardiac arrest (OHCA).[7-9] The outcomes of OHCA depend on dispatcher-assisted and bystander-initiated resuscitation efforts and on initial basic life-support (BLS) actions by bystanders who witness OHCA.[10] The Fukushima nuclear pollution disaster and the large-scale pandemic such as coronavirus disease 2019 (COVID-19) may augment the level of general fear of pollution and infection in the population, which might discourage BCPR.[11,12] However, the impact of large-scale disasters on BCPR actions of laypersons is unknown. This study aimed to investigate whether and how the 2011 earthquake influenced the bystander cardiopulmonary resuscitation (BCPR) and outcomes in OHCA cases witnessed by family, friends, and colleagues in the prefectures that were most affected by the earthquake.

Methods

Data selection and grouping

From the 381,581 nationwide OHCA cases in the All-Japan Utstein-style[13] Registry of the Japanese Fire and Disaster Management Agency, recorded between March 11, 2010 and March 10, 2013, we extracted 108,311 bystander-witnessed cases that did not involve any physician and excluded 2,891 cases that lacked information for analysis. After the disaster, many healthcare providers visited the site. Also, there were many healthcare providers in evacuation shelters and temporary housing. Therefore, we extracted 74,684 family- and friend/colleague-witnessed OHCA cases, excluding cases witnessed by others, to minimize the effect of healthcare providers volunteering for and/or being involved in disaster medical support (Figure 1). The study period included the predisaster year 2010 (2010.3.11–2011.3.10), disaster year 2011 (2011.3.11–2012.3.10), and postdisaster year 2012 (2012.3.11–2013.3.10). Tsunami-affected prefectures, defined as prefectures in which a tsunami with a maximum height of >4 meters was observed, included five prefectures located in the North-East Pacific coast of the Japanese mainland: Aomori, Iwate, Miyagi, Fukushima, and Ibaraki prefectures.[1] The prefectures other than these five tsunami-affected prefectures were designated as other prefectures.

On the basis of the occurrence of aftershocks, number of evacuees in evacuation centers, and resumption of social activities, we determined that 0–23 weeks from March 11, 2011 was the period affected by the disaster. We defined the same period from 2010 to 2012 as the impact phase.

Outcome measures

The primary outcome of this study was provision of BCPR by a family member or a friend/colleague. The secondary outcomes were a neurologically favorable outcome after 1 month, defined as a cerebral performance category score of 1 (good recovery) or 2 (moderate disability)[14] and 1-month survival.

Data analysis

To investigate the validity of the impact phase definition, we analyzed the 4-week average trends in the BCPR rate after the day of disaster in the year 2011 and on the same day (11 March) in the predisaster year of 2010 and postdisaster year of 2012 in the tsunami-affected and other prefectures.

The influence of disaster on BCPR and OHCA outcomes in the tsunami-affected prefectures were investigated using univariate and multivariable logistic regression analyses. The BCPR rates, 1-month survival rates, and neurologically favorable 1-month outcomes were compared between the disaster year (2011) and the predisaster/postdisaster years (2010/2012) during the impact and the postimpact phases in tsunami-affected and other prefectures.

Bystanders exhibit four patterns of behavior against OHCA: BCPR following DA-CPR instruction, bystander-initiated BCPR without DA-CPR, no BCPR despite DA-CPR, and no BCPR without DA-CPR. Furthermore, to clarify the association of the impact phase with dispatcher-assisted and bystander-initiated resuscitation efforts, we calculated the following three indices related to dispatcher-assisted CPR (DA-CPR) and BCPR in accordance with a previous report[15]: 1) sensitivity of DA-CPR for OHCA (=the number of cases for which DA-CPR was attempted divided by the number of cases that did not receive bystander-initiated BCPR without DA-CPR); 2) proportion of bystanders to follow DA-CPR (=the number of cases that received BCPR following DA-CPR divided by the number of cases for which DA-CPR was attempted); and 3) bystander's own performance of BCPR for

OHCA (=the number of cases that received bystander-initiated BCPR without DA-CPR divided by the number of cases for which DA-CPR was not attempted).[10,16]

Univariate analyses were performed using the chi-square test or Fisher's exact probability test for nominal variables. Because the continuous variables analyzed in this study did not show a normal distribution, the Mann–Whiney *U*-test was applied for continuous variables. Multivariable logistic regression analysis for BCPR provision included the factors, which were well known to be associated with BCPR provision: daytime, weekend, patient sex and age, etiology of OHCA (presumed cardiac or not, exogenous origin), family bystander, and DA-CPR instruction. Factors included in multivariable logistic regression analysis for outcomes were daytime, patient sex and age, presumed cardiac etiology, initial rhythm (shockable or not), BCPR provision, family bystander, tracheal intubation and epinephrine administration by paramedics, time interval between witness and emergency call, and time interval between emergency call and emergency medical service (EMS) arrival at patients (EMS response time). All tests were two-tailed, and we considered a probability (P) value < 0.05 to be statistically significant. All statistical analyses were performed using the JMP Pro 15 software (SAS Institute, Cary, NC).

Patient and Public involvement

Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our study.

Results

Number of family- and friends/colleague-witnessed OHCA cases in the tsunami-affected prefectures and other prefectures

A total of 74,684 family- and friends/colleague-witnessed OHCA cases were extracted and analyzed. Among these, the number of family- and friends/colleague-witnessed OHCA cases in the tsunami-affected prefectures was 2061 for the disaster year 2011 and 4019 for 2010/2012. The number of family- and friends/colleague-witnessed OHCA cases in other prefectures was 23720 for 2011 and 44884 for 2010/2012 (Figure 1, lower part). The number of family- and friends/colleague-witnessed OHCA cases during the impact phase was 882 for the disaster year 2011and 1,565 for 2010/2012 in the tsunami-affected prefectures, whereas it was 9696 for 2011 and 17,985 for 2010/2012 in other prefectures.

Validity of the impact phase definition (4-week average trends in BCPR provision after the day of disaster)

The trends in the BCPR rate in 2011 (disaster year) differed from those in 2010/2012 (predisaster and postdisaster years) in the tsunami-affected prefectures (Figure 2, upper panel). In 2010/2012, the BCPR rate remained high (>50%) during weeks 4–23 (corresponding to the spring and summer seasons) whereas it was low (nearly 40%) during weeks 36–43 (winter season) (P for trend: <0.01). However, the BCPR rate remained low except for weeks 8–15 after the disaster, and no seasonal variations were observed in 2011 (P for trend: 0.83). The impact phase coincided with the period during which the differences in the 4-week averages of BCPR between 2011 and 2010/2012 were recognized in the tsunami-affected prefectures.

On the other hand, in other prefectures (the tsunami-not-affected prefectures), the trend of BCPR rate was the same in 2011 (year of disaster) and 2010/2012. The BCPR rate remained at nearly 40% throughout the 3 years, regardless of the impact phase of the disaster (before and after the disaster; Figure 2, lower panel). Furthermore, there were no obvious seasonal variations (P for trend: 0.43 in 2011 and 0.96 in 2010/2012).

The average rates of BCPR during the impact phase were 42.5% (375/882) for the disaster year 2011 and 48.2% (754/1,565) for 2010/2012 in Tsunami-affected prefectures and 40.3% (3,907/9,696) for 2011 and 40.2% (7,263/17,985) for 2010/2012 in other prefectures.

Differences in the backgrounds and characteristics of OHCA between the disaster year and the predisaster/postdisaster years

In the tsunami-affected prefectures, during the impact phase, the incidence of OHCA during weekends and the proportion of cases of presumed cardiac etiology in 2011 were higher than those in 2010/2012, whereas the rate of DA-CPR was lower. As expected, transportation time from the scene to the hospital was prolonged in 2011. During the postimpact phase, there was no significant difference in backgrounds between 2011 and 2010/2012 (Table 1).

In other prefectures, significant differences in some prehospital confounders were observed between 2011 and 2010/2012 during the impact and postimpact phases. However, the differences in these parameters were very small (Supplemental Table 1).

Table 1 Background, characteristics, and time factors of family- and friend/colleague-witnessed out-of-hospital cardiac arrest cases in tsunami-affected prefectures

Background, characteristics, and time factors	Impact phase		Unadjusted OR (95% CI) a) or P-value	Postimpact phase		Unadjusted OR (95% CI) a) or P-value
	2011 (N = 882)	2010/2012 (N = 1,565)		2011 (N = 1,179)	2010/2012 (N = 2,454)	
Family-witnessed patients, No. (%)	783 (88.8)	1,404 89.7)	0.91 (0.70–1.18)	1,074 (91.1)	2,219 (90.4)	1.08 (0.85–1.38)
Daytime (7:00 a.m.–7:00 p.m.), No. (%)	520 (59.0)	950 (60.7)	0.93 (0.79–1.10)	682 (57.9)	1,485 (60.5)	0.90 (0.79–1.03)
Weekend, No. (%)	141 (16.0)	192 (12.3)	**1.36 (1.08–1.72)**	146 (12.4)	338 (13.8)	0.89 (0.72–1.09)
Age, median (IQR), y	78 (65–84)	76 (63–84)	0.12	77 (66–84)	78 (67–85)	0.17
Male patient, No. (%)	598 (67.8)	1,002 (64.0)	1.18 (1.00–1.41)	734 (62.3)	1,525 (62.1)	1.01 (0.87–1.16)
Presumed cardiac etiology, No. (%)	554 (62.8)	877 (56.0)	**1.33 (1.12–1.57)**	725 (61.5)	1,443 (58.8)	1.12 (0.97–1.29)
Exogenous origin b), No. (%)	102 (11.6)	206 (13.2)	0.86 (0.67–1.11)	118 (10.0)	259 (10.6)	0.94 (0.75–1.19)
Shockable initial rhythm, No. (%)	162 (18.4)	271 (17.3)	1.07 (0.87–1.33)	185 (15.7)	345 (14.1)	1.14 (0.94–1.38)
Dispatcher-assisted CPR, No. (%)	433 (49.1)	835 (53.4)	**0.84 (0.72–0.99)**	598 (50.7)	1,240 (50.5)	1.01 (0.88–1.16)
Defibrillation by bystanders with an AED, No. (%)	4 (0.5)	9 (0.6)	0.79 (0.24–2.58)	11 (0.9)	12 (0.6)	1.65 (0.73–3.75)
Epinephrine administration by paramedics, No. (%)	153 (17.4)	256 (16.4)	1.07 (0.86–1.34)	231 (19.6)	448 (19.7)	1.00 (0.84–1.19)
Tracheal intubation by paramedics, No. (%)	78(8.8)	161 (10.3)	0.85 (0.64–1.12)	103 (8.7)	251 (10.2)	0.84 (0.66–1.07)
Time intervals, median (IQR), min						
Witness-to-emergency call	2 (0–5)	2 (0–5)	0.71	2 (0–5)	2 (0–5)	0.49
EMS response time c)	8 (7–11)	9 (7–11)	0.45	9 (7–11)	9 (7–12)	0.11
EMS arrival at patient-to-arrival at the hospital	21 (16–28)	20 (15–27)	**< 0.05**	22 (16–29)	22 (16–29)	0.74

OR, odds ratio; CI, confidence interval; IQR, interquartile range; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; EMS, emergency medical service; impact phase, 0-23 weeks from March 11; postimpact phase, from 24 weeks after March 11 until March 11 of the following year

a) 2010/2012 as a reference

b) Asphyxia, submersion, hypothermia, poisoning, and trauma

c) Time interval between emergency call and EMS arrival at patient

Supplemental Table 1 Background, characteristics, and time factors of family- and friend/colleague-witnessed out-of-hospital cardiac arrest cases in non-affected prefectures

Background, characteristics, and time factors	Impact phase		Unadjusted OR (95% CI) [a] or P-value	Postimpact phase		Unadjusted OR (95% CI) [a] or P-value
	2011 (N = 9,696)	2010/2012 (N = 17,985)		2011 (N = 14,024)	2010/2012 (N = 26,899)	
Family-witnessed patients, No. (%)	8,771 (90.5)	16,211 (90.1)	1.04 (0.95–1.13)	12,679 (90.4)	24,452 (90.9)	0.94 (0.88–1.01)
Daytime (7:00 a.m.–7:00 p.m.), No. (%)	5,741 (59.2)	10,653 (59.2)	1.00 (0.95–1.05)	8,285 (59.1)	16,124 (59.9)	0.97 (0.93–1.01)
Weekend, No. (%)	1,362 (14.1)	2,424 (13.5)	1.05 (0.98–1.13)	1,971 (14.1)	3,659 (13.6)	1.04 (0.98–1.10)
Age, median (IQR), y	77 (66–85)	77 (66–85)	0.57	77 (66–85)	78 (67–85)	0.05
Male patient, No. (%)	6,113 (63.1)	11,429 (63.6)	0.98 (0.93–1.03)	8,846 (63.1)	16,795 (62.4)	1.03 (0.99–1.07)
Presumed cardiac etiology, No. (%)	5,661 (58.4)	10,483 (58.3)	1.00 (0.96–1.06)	8,220 (58.6)	16,085 (59.8)	**0.95 (0.91–0.99)**
Exogenous origin [b], No. (%)	1,232 (12.7)	2,202 (12.2)	1.04 (0.97–1.12)	1,709 (12.2)	2,845 (10.6)	**1.17 (1.10–1.25)**
Shockable initial rhythm, No. (%)	1,399 (14.4)	2,598 (14.5)	1.00 (0.93–1.07)	1,979 (14.1)	3,676 (13.7)	1.04 (0.98–1.10)
Dispatcher-assisted CPR, No. (%)	4,882 (50.4)	8,833 (49.1)	1.05 (1.00–1.10)	7,139 (50.9)	13,640 (50.7)	1.01 (0.97–1.05)
Defibrillation by bystanders with an AED, No. (%)	67 (0.7)	145 (0.8)	0.60 (0.64–1.15)	101 (0.7)	197 (0.8)	0.91 (0.72–1.16)
Epinephrine administration by paramedics, No. (%)	2,097 (21.6)	3,891 (21.6)	1.00 (0.94–1.06)	3,084 (22.0)	6,106 (23.5)	**0.92 (0.88–0.97)**
Tracheal intubation by paramedics, No. (%)	845 (8.7)	1,697 (9.4)	**0.92 (0.84–0.99)**	1,246 (8.9)	2,500 (9.3)	0.95 (0.89–1.02)
Time intervals, median (IQR), min						
Witness-to-emergency call	2 (0–5)	2 (0–5)	**<0.005**	2 (0–5)	2 (0–5)	0.24
EMS response time [c]	8 (7–11)	8 (7–10)	0.10	8 (7–11)	8 (7–11)	0.86
Arrival at the patient-to-arrival at the hospital	23 (18–30)	23 (18–30)	0.08	23 (18–30)	24 (18–31)	**<0.01**

IQR, interquartile range; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; EMS, emergency medical service; impact phase, 0-23 weeks from March 11; postimpact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

a) 2010/2012 as a reference

b) Asphyxia, submersion, hypothermia, poisoning, and trauma

c) Time interval between emergency call and EMS arrival at patient

Multivariable regression analyses of the differences in BCPR provision and outcomes between the disaster year and the predisaster/postdisaster years

In the tsunami-affected prefectures, the rates of BCPR, 1-month survival and 1-month neurologically favorable outcome in 2011 were significantly lower than those in 2010/2012 during the impact phase. During the postimpact phase, no significant difference in any of these parameters was observed between 2011 and 2010/2012. (Table 2). In other prefectures, significant differences were observed neither during the impact phase nor during the postimpact phase (Supplemental Table 2).

As shown in the footnotes, the multivariable regression analysis disclosed that DA-CPR (with adjusted ORs ranging from 7.07 to 9.27) was a common and major factor associated with BCPR provision, regardless of the phase and prefecture. The major factors associated with a neurologically favorable outcome included shockable initial rhythm and EMS response time. Notably, the adjusted OR (95% confidence interval [CI]) of shockable initial rhythms for neurologically favorable outcome was much higher during the impact phase than during the postimpact phase in tsunami-affected prefectures (12.4 [7.3–20.9] *vs.* 7.1 [4.7–10.8], interaction test, $P < 0.01$).

Table 2 Phasic comparisons of bystander cardiopulmonary resuscitation and outcomes between 2011 and 2010/2012 in tsunami-affected prefectures

BCPR and outcomes	Impact phase		Adjusted OR (95% CI) with 2010/2012 as a reference	Postimpact phase		Adjusted OR (95% CI) with 2010/2012 as a reference
	2011 (N = 882)	2010/2012 (N = 1,565)		2011 (N = 1,179)	2010/2012 (N = 2,454)	
BCPR rate, No. (%)	375 (42.5)	754 (48.2)	**0.82 (0.68–0.99)**[a)]	510 (43.3)	1,068 (43.5)	0.99 (0.84–1.16)[d)]
1-month survival, No. (%)	75 (8.5)	168 (10.7)	**0.72 (0.52–0.99)**[b)]	103 (8.7)	200 (8.2)	1.02 (0.78–1.33)[e)]
Neurologically favorable outcome, No. (%)	35 (4.0)	82 (5.2)	**0.62 (0.38–0.98)**[c)]	48 (4.1)	107 (4.4)	0.89 (0.61–1.29)[f)]

BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11; postimpact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

a) Among the other factors including in the logistic regression model, age (Adjusted OR; 95% CI, 0.93; 0.88−0.99/10 years), family bystander (0.52: 0.38−0.71), and DA-CPR provision (7.07; 5.89−8.5) were significantly associated with BCPR rate.

b) Among the other factors including in the logistic regression model, age (0.81; 0.75−0.88/10 years), EMS response time (0.38; 0.31−0.48/10 min), time interval of witness-to-emergency call (0.71; 0.59−0.91/10 min), male patients (1.43; 1.01−2.03), daytime (7:00 a.m.–7:00 p.m.) OHCA (1.54; 1.13−2.11), shockable initial rhythm (6.93; 4.92−9.76), and epinephrine administration (0.64; 0.41−0.99) were significantly associated with 1-month survival.

c) Among the other factors including in the logistic regression model, age (0.76; 0.69–0.85/10 years), EMS response time (0.29; 0.23–0.39/10 min), time interval of witness-to-emergency call (0.54; 0.41–0.79/10 min), shockable initial rhythm (12.4; 7.34–20.9), and epinephrine administration (0.18; 0.07–0.44) were significantly associated with neurologically favorable outcome.

d) Among the other factors including in the logistic regression model, age (0.92; 0.87–0.97/10 years), family bystander (0.49: 0.37–0.64), and DA-CPR provision (9.27; 7.92–10.9) were significantly associated with BCPR rate.

e) Among the other factors including in the logistic regression model, age (0.86; 0.80–0.92/10 years), EMS response time (0.46; 0.39–0.56/10 min), time interval of witness-to-emergency call (0.66; 0.57–0.80/10 min), cardiac etiology (0.67; 0.50−0.89), and shockable initial rhythm (6.93; 4.92–9.76) were significantly associated with 1-month survival.

f) Among the other factors including in the logistic regression model, age (0.87; 0.79–0.97/10 years), EMS response time (0.39; 0.31–0.51/10 min), time interval of witness-to-emergency call (0.53; 0.43–0.69/10 min), shockable initial rhythm (12.4; 7.34–20.9), and cardiac etiology (1.53; 1.07–2.2) were significantly associated with neurologically favorable outcome.

Supplemental Table 2 Phasic comparisons of bystander cardiopulmonary resuscitation and outcomes between 2011 and 2010/2012 in non-affected prefectures

BCPR and outcomes	Impact phase		Adjusted OR (95% CI) with 2010/2012 as a reference	Postimpact phase		Adjusted OR (95% CI) with 2010/2012 as a reference
	2011 (N = 9,696)	2010/2012 (N = 17,985)		2011 (N = 14,024)	2010/2012 (N = 26,899)	
BCPR rate, No. (%)	3,907 (40.3)	7,263 (40.4)	0.96 (0.91–1.02)[a)]	5,801 (41.4)	11,059 (41.1)	1.01 (0.96–1.05)[b)]
1-month survival, No. (%)	805 (8.3)	1,509 (8.4)	1.00 (0.91–1.10)	1,146 (8.2)	2,120 (7.9)	1.02 (0.94–1.10)
Neurologically favorable outcome, No. (%)	413 (4.3)	735 (4.1)	1.07 (0.93–1.22)[)]	557 (4.0)	1,056 (3.9)	1.01 (0.90–1.13)

BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11; postimpact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

a) Among the other factors including in the logistic regression model, age (adjusted OR; 95% CI, 0.94; 0.92–0.95/10 years), family bystander (0.50: 0.45–0.55), cardiac etiology (1.1; 1.03−1.17), and DA-CPR provision (8.60; 8.12–9.11) were significantly associated with BCPR rate.

b) Among the other factors including in the logistic regression model, age (0.93; 0.92–0.95/10 years), family bystander (0.50: 0.46–0.55), cardiac etiology (1.1; 1.04−1.15), and DA-CPR provision (8.99; 8.57–9.42) were significantly associated with BCPR rate.

Analysis of indices for dispatcher-assisted and bystander-initiated resuscitation efforts

In tsunami-affected prefectures, DA-CPR sensitivity and bystander's compliance to DA-CPR appeared to be suppressed during the impact phase in 2011, being 55.8% and 62.1%, respectively in 2011, and 60.0% and 69.5%, respectively in 2010/2012. However, the difference between 2011 and 2010/2012 was significant only for bystander's compliance to DA-CPR (Adjusted OR; 95% CI, 0.72; 0.57–0.92). During the postimpact phase, there were no significant differences in these indices between 2011 and 2010/2012. Difference in the performance of BCPR was detected neither during the impact phase nor during the postimpact phase (Table 3).

In other prefectures, none of the three indices differed between 2011 and 2010/2012; neither during the impact phase nor during the postimpact phase (Supplemental Table 3).

Table 3 Phasic comparisons of indices for dispatcher-assisted and bystander-initiated resuscitation efforts between 2011 and 2010/2012 in tsunami-affected prefectures

Indices related to DA-CPR and BCPR	Impact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference	Postimpact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference
	2011	2010/2012		2011	2010/2012	
DA-CPR sensitivity, No./total (%)	433/776 (55.8)	835/1,391 (60.0)	0.84 (0.70–1.00)	598/1,062 (56.3)	1,240/2,224 (55.8)	1.02 (0.88–1.19)
Bystander's compliance to DA-CPR, No./total (%)	**269/433 (62.1)**	**255/835 (69.5)**	**0.72 (0.57–0.92)**	393/598 (65.7)	838/1,240 (67.6)	0.92 (0.75–1.13)
Bystander`s own performance of BCPR, No./total (%)	106/449 (23.6)	174/730 (23.8)	0.99 (0.72–1.07)	117/581 (20.1)	230/1,214 (19.0)	1.08 (0.84–1.39)

DA-CPR, dispatcher-assisted cardiopulmonary resuscitation; BCPR, bystander cardiopulmonary resuscitation;
impact phase, 0-23 weeks from March 11;postimpact phase, from 24 weeks after March 11 until March 11 of the following year;
OR, odds ratio; CI, confidence interval.

Supplemental Table 3 Phasic comparisons of indices for dispatcher-assisted and bystander-initiated resuscitation efforts between 2011 and 2010/2012 in non-affected prefectures

Indices related to DA-CPR and BCPR	Impact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference	Postimpact phase		Unadjusted OR (95% CI) with 2010/2012 as a reference
	2011	2010/2012		2011	2010/2012	
DA-CPR sensitivity, No./total (%)	4,882/8,834 (55.3)	8,833/16,350 (54.0)	1.05 (0.99–1.11)	7,139/12,788 (55.8)	13,640/24,565 (55.5)	1.05 (0.99–1.11)
Bystander's compliance to DA-CPR, No./total (%)	3,041/4,882 (62.3)	5,628/8,833 (63.7)	0.94 (0.88–1.01)	8,725/13,640 (63.9)	8,725/13,640 (64.0)	1.00 (0.94–1.06)
Bystander`s own performance of BCPR, No./total (%)	862/4,814 (17.9)	1,635/9,152 (17.9)	1.00 (0.92–1.10)	1,236/6,885 (18.0)	2,334/13,259 (17.6)	1.02 (0.95–1.11)

DA-CPR, dispatcher-assisted cardiopulmonary resuscitation; BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11; postimpact phase, from 24 weeks after March 11 until March 11 of the following year; OR, odds ratio; CI, confidence interval.

Discussion

In disaster mental health, the reactions of the community and the individual are usually divided to four phases (heroic phase, honeymoon phase, disillusionment phase, and restoration phase),[17] although the duration of these phases may vary depending on the scale and type of disaster. The impact phase in this study covers the period from heroic phase to disillusionment phase. This relatively long impact phase and the wide area affected by the disaster may contribute to the detection of a significant impact of the disaster in this study.

Loss of family members and friends, lack of employment stability, or extensive damage to property, resulting in loss of or a decrease in income are reported as risk factors for the development of disaster-related mental health problems.[18-20] In this study, the BCPR rate in tsunami-affected prefectures temporally increased during the 8–11 weeks after the disaster but remained low thereafter, reflecting a temporal relief in anxiety due to increased provision of supplies and accommodation during the "honeymoon phase" and recognition of depressed economic resilience, repeated aftershocks, and escape or avoidance behavior[21] during disillusionment phase.

The BCPR rate varies between countries, but the BCPR rate in Japan in the 3 years from 2010 to 2012 was as high as or higher than that in the European Union and United States.[22,23] In comparison with other prefectures, a higher BCPR rate in tsunami-affected prefectures might be due to the higher proportion of citizens having attended BLS training courses every year.[24-26] People with CPR training are known to perform BCPR more than those without an experience of CPR training.[27] Compared with the patients with OHCA in the other (nonaffected) prefectures, those in the tsunami-affected prefectures were subject to relatively higher BCPR rates in the predisaster and postdisaster years, particularly during the spring and summer seasons, which is identical to that in the impact phase that we determined. Major industries in the affected areas included fishery, agriculture, and food processing managed by corporative unions. The population, particularly the elderly, typically endures a rugged winter at home, and their social activities diminish at the end of autumn and over the winter. Meanwhile, during spring and summer, citizens including the elderly cooperate in agricultural work and preparation of social events, including festivals and outdoor events.[28] Increased collaborative activities of citizens, including the elderly, in these seasons and accommodativeness as a general personality trait of the citizens might be one of the reasons for this seasonal variation in BCPR rate because OHCA cases in these seasons are frequently managed by many bystanders, including those with training experience.

Surveys on citizens and EMS personnel who survived the disaster in tsunami-affected prefectures reported that more than half of them lost their family and friends/colleagues.[29] People who died during the disaster were mostly the elderly (54.4%), suggesting that the proportion of trained bystanders was not affected by the disaster.[30] Thus, decreased rates of BCPR and DA-CPR may be attributed to the decreased collaborative social activities and psychological reactions of dispatchers and bystanders, which may interfere with communication between bystanders and dispatchers.

The 2011 earthquake and the earthquake-associated tsunami were followed by a nuclear accident in the Fukushima prefecture. People who had a false understanding of radiation were afraid to interact with evacuees and avoided contact. For these reasons, it is highly possible that nuclear pollution may interfere with bystander-initiated CPR provision due to augmented fear of nuclear pollution during CPR, particularly of refugees from the polluted area.[31] Recent studies on the COVID-19 pandemic on BCPR support this assumption.[12]

It might be difficult to prevent the BCPR and certain outcomes from deteriorating during the impact phase. The analysis of the three indices related to DA-CPR and BCPR showed that only the level of voluntary performance of BCPR was preserved during the impact phase in tsunami-affected prefectures. Because BLS training is known to augment the willingness to provide voluntary BCPR without DA-CPR[32], systematic BLS training to citizens may be effective for preservation of voluntary performance of BCPR in the event of a disaster. Furthermore, this study showed that the dependence of outcome on initial shockable rhythm was augmented during the impact phase in Tsunami-affected prefecture. However, incidences of public access to defibrillation (defibrillation by bystanders with an AED) during the study period was extremely low (<1%), particularly during the impact phase in Tsunami-affected prefecture (0.6%). Public-Access Defibrillation has definitive impact on the outcome of OHCA[33]. Therefore, BLS training including AED use and its supply might function as preparedness for disaster.

Limitation

The present study has several strengths. Firstly, this study focused on alterations in bystander-initiated and dispatcher-instructed BCPR after a large-scale disaster. Secondly, not only before-after comparisons but also differences in trends were analyzed between tsunami-affected and -unaffected prefectures using a large nationwide dataset. However, this study also has several limitations. First, although the catastrophe occurred in the coastal areas of some of the prefectures, the analyses were performed after dividing the prefectures. In tsunami-affected prefectures, no major urban areas were located in the coastal area, and differences in BCPR intervention between urban and rural areas[34] were excluded in this study. Second, bystander-specific data, such as age, sex, and training experience were not included in the database and therefore not available for study. Third, it was not possible to study whether the bystanders were actually psychologically affected. Therefore, these factors potentially associated with BCPR quality might affect the quality of the study results.[35] Fourth, no comparative analysis was performed with the results of other disasters. Fifth, since this study is based on one disaster that occurred in Japan, it is unclear whether the results will apply to other disasters as well. Sixth, as with other observational studies, the validity of data is another potential limitation.

Conclusions

A large-scale disaster may influence bystander-initiated CPR and outcomes of OHCA witnessed by family/friends/colleagues. BLS training might serve as preparedness for disaster and major accidents.

Acknowledgments

We thank the EMS personnel and FDMA in Japan for their cooperation in collecting and managing the All-Japan Utstein Registry data. TU and KT equally contributed to this article as first authors.

Article information

Corresponding Author: Tomoyuki Ushimoto, MD, PhD, Department of Emergency Medicine, Kanazawa Medical University, 1-1 Daigaku, Uchinada-machi, Kahoku-gun, Ishikawa 920-0293, Japan

Contributions: The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

TU and KT had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. TU and KT equally contributed to this article as first authors.

Study concept and design: TU, KT and HI.

Acquisition, analysis, and interpretation of data: All authors.

Drafting of the manuscript: AY, HM, HI, KT and TU.

Clinical revision of the manuscript for important intellectual content: TU, HI, KT and YW.

Statistical analysis: TU, KT, and HI.

Obtained funding: None.

Administrative, technical, or material support: HI and YW.

Study supervision: HI and YW.

Contribution, v) the inclusion of electronic links from the Contribution to third party material wherever it may be located; and, vi) licence any third party to do any or all of the above.

Competing Interest statement: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: This study was approved by the institutional review board of the Ishikawa Medical Control Council and conducted by the study group comprising of members of the Ishikawa Medical Control Council and their collaborators. Patient consent was not required for use of the secondary data.

Transparency: TU affirmed that the manuscript is an honest, accurate, and transparent account of the study.

Funding: None.

Data sharing: No additional data available.

Additional information: Some references used in this article are available online and cited as embedded hyperlinks.

References

1. Department of International Affairs, Japan Science and Technology Agency. The Great East Japan Earthquake Information from Official Websites, 2011 (Accessed 8 December 2021, at https://www.jst.go.jp/pr/pdf/great_east_japan_earthquake.pdf).

2. Fire and Disaster Management Agency (Japan). Great East Japan Earthquake (in Japanese) (Accessed 8 December 2021, at https://www.fdma.go.jp/disaster/higashinihon/).

3. Japan Meteorological Agency. The 2011 Great East Japan Earthquake: Number of aftershock (in Japanese) (Accessed 8 December 2021, at http://www.data.jma.go.jp/svd/eqev/data/2011_03_11_tohoku/aftershock/).

4. Reconstruction Agency (Japan). Recovery and Reconstruction from the Great East Japan Earthquake, 2012 (in Japanese) (Accessed 8 December 2021, at https://www.reconstruction.go.jp/topics/20130104_higashinippondaishinsai_fukkoh.pdf).

5. Ozdemir O, Boysan M, Guzel Ozdemir P, Yilmaz E. Relationships between posttraumatic stress disorder (PTSD), dissociation, quality of life, hopelessness, and suicidal ideation among earthquake survivors. Psychiatry Res 2015; 228: 598-605. doi: 10.1016/j.psychres.2015.05.045.

6. Makwana N. Disaster and its impact on mental health: A narrative review. J Family Med Prim Care 2019; 8: 3090-3095. doi: 10.4103/jfmpc.jfmpc_893_19.

7. Leor J, Poole WK, Kloner RA. Sudden cardiac death triggered by an earthquake. N Engl J Med 1996; 34: 413-419.

8. Ogawa K, Tsuji I, Shiono K, Hisamichi S. Increased acute myocardial infarction mortality following the 1995 Great Hanshin-Awaji earthquake in Japan. Int J Epidemiol 2002; 29: 449-455.

9. Sokejima S, Nakatani Y, Kario K, Kayaba K, Minowa M, Kagamimori S. Seismic intensity and risk of cerebrovascular stroke: 1995 Hanshin-Awaji earthquake. Prehosp Disaster Med 2004; 19: 297-306.

10. Yamashita A, Maeda T, Myojo Y, Wato Y, Ohta K, Inaba H. Temporal variations in dispatcher-assisted and bystander-initiated resuscitation efforts. Am J Emerg Med 2018; 36: 2203-2210. doi: 10.1016/j.ajem.2018.03.080.

11. Savastano S, Vanni V. Cardiopulmonary resuscitation in real life: The most frequent fears of lay rescuers. Resuscitation 2011; 82: 568-571. doi:10.1016/j.resuscitation.2010.10.010

12. Pranata R, Lim MA, Yonas E, Siswanto BB, Meyer M. Out-of-hospital cardiac arrest prognosis during the COVID-19 pandemic. Intern Emerg Med 2020; (0123456789): 7-9. doi:10.1007/s11739-020-02428-7.

13. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International liaison Committee on resuscitation. Circulation 2004; 110: 3385–97.

14. Jennett B, Bond M. Assessment of outcome after severe brain damage. Lancet 1976; 1: 480–4. doi:10.1016/S0140-6736(75)92830-5.

15. Maeda T, Yamashita A, Myojo Y, Wato Y, Inaba H. Augmented survival of out-of-hospital cardiac arrest victims with the use of mobile phones for emergency communication under the DA-CPR protocol getting information from callers beside the victim. Resuscitation 2016; 107: 80-87. doi:10.1016/j.resuscitation.2016.08.010

16. Nishi T, Kamikura T, Funada A, Myojo Y, Ishida T, Inaba H. Are regional variations in activity of dispatcher-assisted cardiopulmonary resuscitation associated with out of-hospital cardiac arrests outcomes? A nation-wide population-based cohort study. Resuscitation 2016; 98: 27–34. doi: 10.1016/j.resuscitation.2015.10.004.

17. Math SB, Nirmala MC, Moirangthem S, Kumar NC. Disaster Management: Mental Health Perspective. Indian J Psychol Med 2015; 37: 261-71. doi: 10.4103/0253-7176.162915.

18. Norris FH, Friedman MJ, Watson PJ, Byrne CM, Diaz E, Kaniasty K. 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981-2001. Psychiatry 2002; 65: 207-39.

19. Başoğlu M, Kiliç C, Salcioğlu E, Livanou M. Prevalence of posttraumatic stress disorder and comorbid depression in earthquake survivors in Turkey: an epidemiological study. J Trauma Stress 2004; 17: 133-41.

20. van Griensven F, Chakkraband ML, Thienkrua W, et al. Mental health problems among adults in tsunami-affected areas in southern Thailand. JAMA 2006; 296: 537-48.

21. Avoidance behavior. (n.d.) Miller-Keane Encyclopedia and Dictionary of Medicine, Nursing, and Allied Health, Seventh Edition. (2003). (Retrieved 8 December 2021 from https://medical-dictionary.thefreedictionary.com/Avoidance+behavior).

22. Jan-Thorsten G, Rolf L, Rudolph WK, et al. Corrigendum to "EuReCa ONE-27 Nations, ONE Europe, ONE Registry A prospective one month analysis of out-of-hospital cardiac arrest outcomes in 27 countries in Europe". Resuscitation 2016; 105: 188-195.

23. Gabriel R, Mattias R, Martin J, et al. Survival in Out-of-Hospital Cardiac Arrest After Standard Cardiopulmonary Resuscitation or Chest Compressions Only Before Arrival of Emergency Medical Services: Nationwide Study During Three Guideline Periods. Circulation 2019; 139: 2600–2609.

24. Fire and Disaster Management Agency (Japan). Rescue operations and first-aid, 2010 (in

Japanese) (Accessed 8 December 2021, at https://www.fdma.go.jp/pressrelease/houdou/items/h23/2312/231216_1houdou/02_1.pdf).

25. Fire and Disaster Management Agency (Japan). Rescue operations and first-aid, 2011 (in Japanese) (Accessed 8 December 2021, at https://www.fdma.go.jp/publication/rescue/items/kkkg_h24_01_kyukyu.pdf).

26. Fire and Disaster Management Agency (Japan). Rescue operations and first-aid, 2012 (in Japanese) (Accessed 8 December 2021, at https://www.fdma.go.jp/publication/rescue/items/kkkg_h25_01_kyukyu.pdf)

27. Robert G, Andrew S L, Patricia C, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 10. Education and implementation of resuscitation. Resuscitation 2015; 95: 288-301.

28. Portal Site of Official Statistics of Japan website. 2010 Population Census (Accessed 8 December 2021, at http://www.stat.go.jp/english/data/kokusei/2010/summary.html).

29. Fire and Disaster Management Agency (Japan). Report, 2013 (in Japanese) (Accessed 8 December 2020, at https://www.fdma.go.jp/singi_kento/kento/kento098.html).

30. Ministry of Health, Labor and Welfare (Japan). Overview of 2011 vital statistics, death situation due to the Great East Japan Earthquake from the viewpoint of vital statistics. (in Japanese) (Accessed 8 December 2021, at https://www.mhlw.go.jp/toukei/saikin/hw/jinkou/kakutei11/dl/14_x34.pdf).

31. Maeda M, Oe M. Mental Health Consequences and Social Issues After the Fukushima Disaster. Asia Pac J Public Health 2017; 29: 36-46. doi:10.1177/1010539516689695.

32. Tanigawa K, Iwami T, Nishiyama C, et al. Are trained individuals more likely to perform bystander CPR? An observational study. Resuscitation 2011; 82(5):523-8. doi: 10.1016/j.resuscitation.2011.01.027. Epub 2011 Feb 26.

33. Kitamura T, Kiyohara K, Sakai T, et al. Public-Access Defibrillation and Out-of-Hospital Cardiac Arrest in Japan. N Engl J Med 2016; 375:1649-1659. doi: 10.1056/NEJMsa1600011.

34. Mathiesen W, Bjørshol C, Kvaløy J, Søreide E. Effects of modifiable prehospital factors on survival after out-of-hospital cardiac arrest in rural versus urban areas. Crit Care 2018; 22: 99. doi:10.1186/s13054-018-2017-x.

35. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without instruction. Resuscitation 2014; 85: 492-8. doi:10.1016/j.resuscitation.2013.12.019.

Legends to figures

Figure 1: Data selection and subgroup extraction

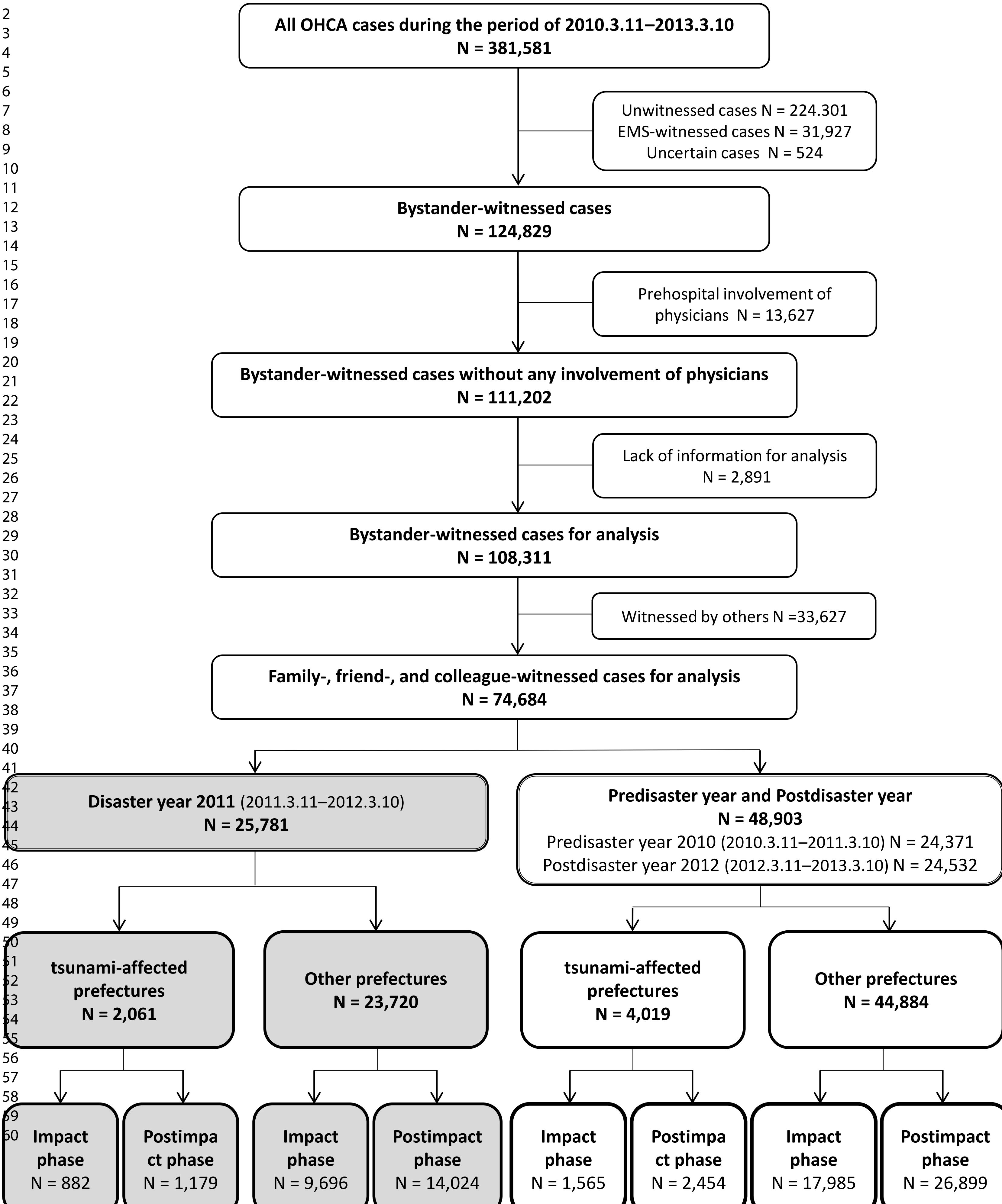
OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service.

Figure 2: Four-week average trends of bystander cardiopulmonary resuscitation in tsunami-affected prefectures and other prefectures

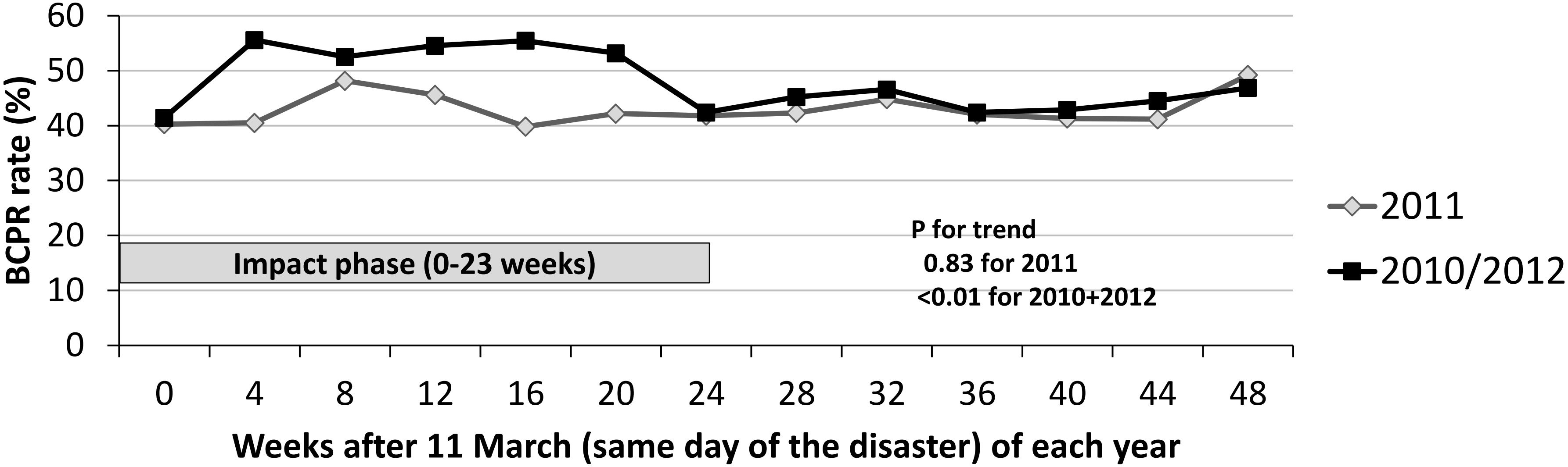
BCPR, bystander cardiopulmonary resuscitation; impact phase, 0-23 weeks from March 11.

Supplemental Figure: Analysis of the disaster status and social responses

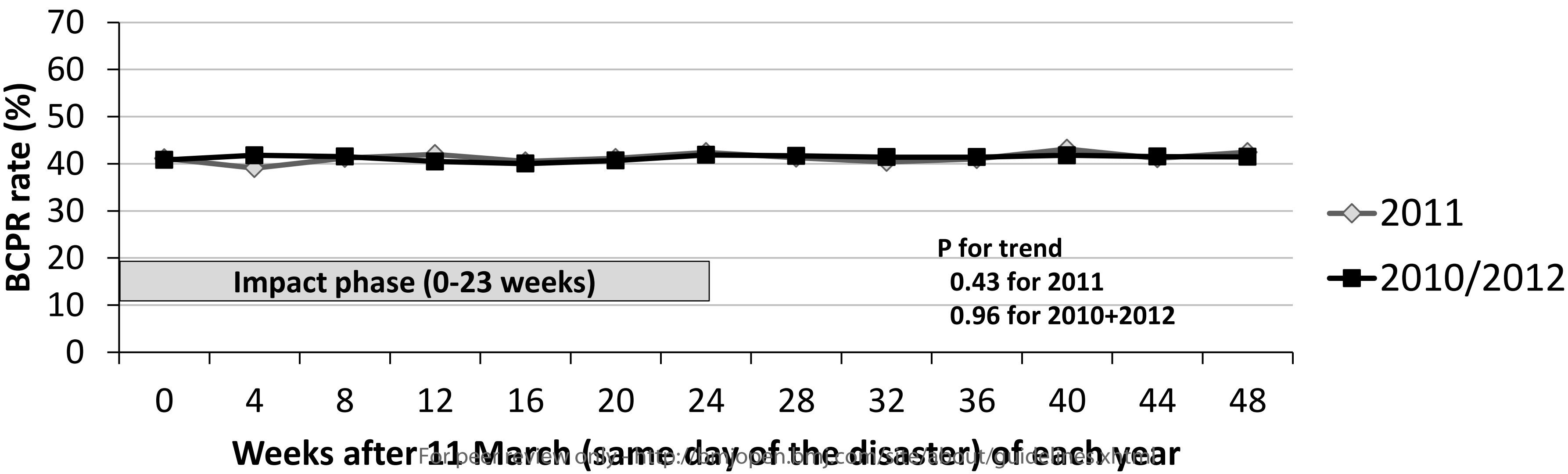
Mw, Moment magnitude.

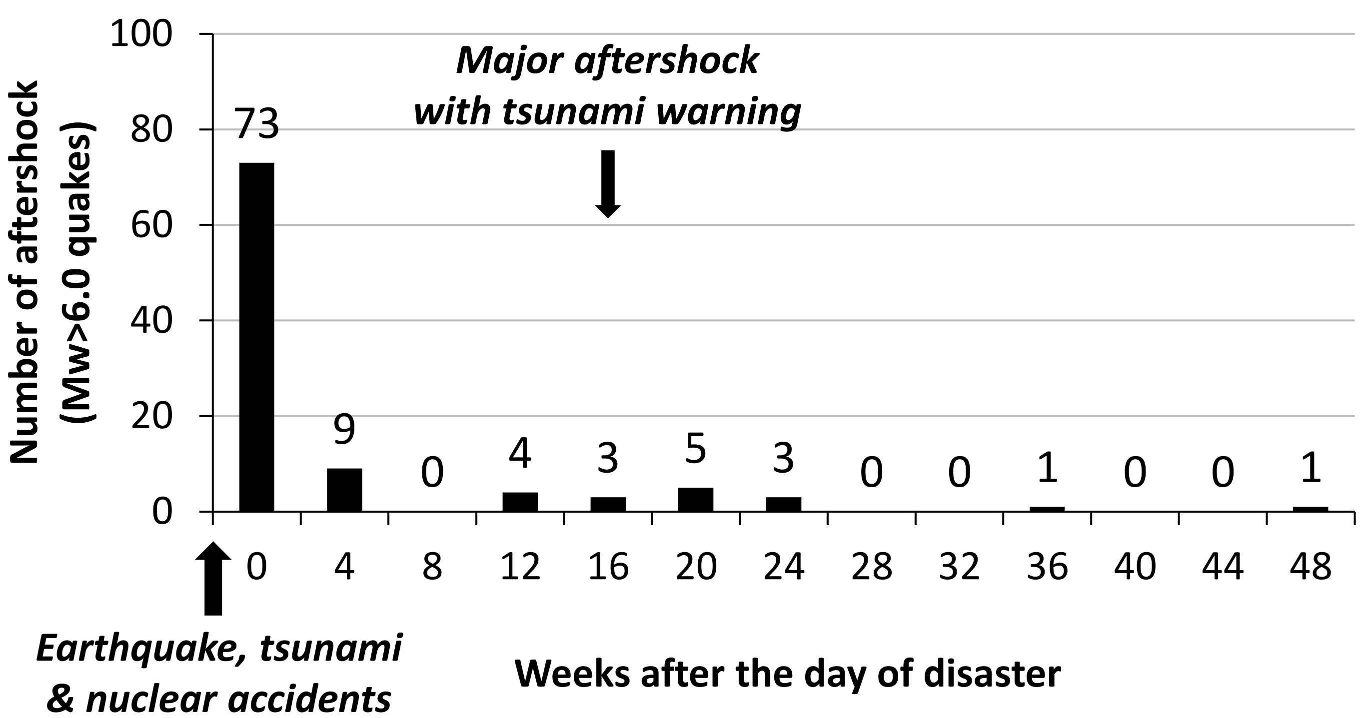

All OHCA cases during the period of 2010.3.11–2013.3.10
N = 381,581
Unwitnessed cases N = 224.301
EMS-witnessed cases N = 31,927
Uncertain cases N = 524
Bystander-witnessed cases
N = 124,829
Prehospital involvement of physicians N = 13,627
Bystander-witnessed cases without any involvement of physicians
N = 111,202
Lack of information for analysis
N = 2,891
Bystander-witnessed cases for analysis
N = 108,311
Witnessed by others N =33,627
Family-, friend-, and colleague-witnessed cases for analysis
N = 74,684
Disaster year 2011 (2011.3.11–2012.3.10)
N = 25,781
Predisaster year and Postdisaster year
N = 48,903
Predisaster year 2010 (2010.3.11–2011.3.10) N = 24,371
Postdisaster year 2012 (2012.3.11–2013.3.10) N = 24,532
tsunami-affected prefectures
N = 2,061
Other prefectures
N = 23,720
tsunami-affected prefectures
N = 4,019
Other prefectures
N = 44,884
Impact phase
N = 882
Postimpact phase
N = 1,179
Impact phase
N = 9,696
Postimpact phase
N = 14,024
Impact phase
N = 1,565
Postimpact phase
N = 2,454
Impact phase
N = 17,985
Postimpact phase
N = 26,899

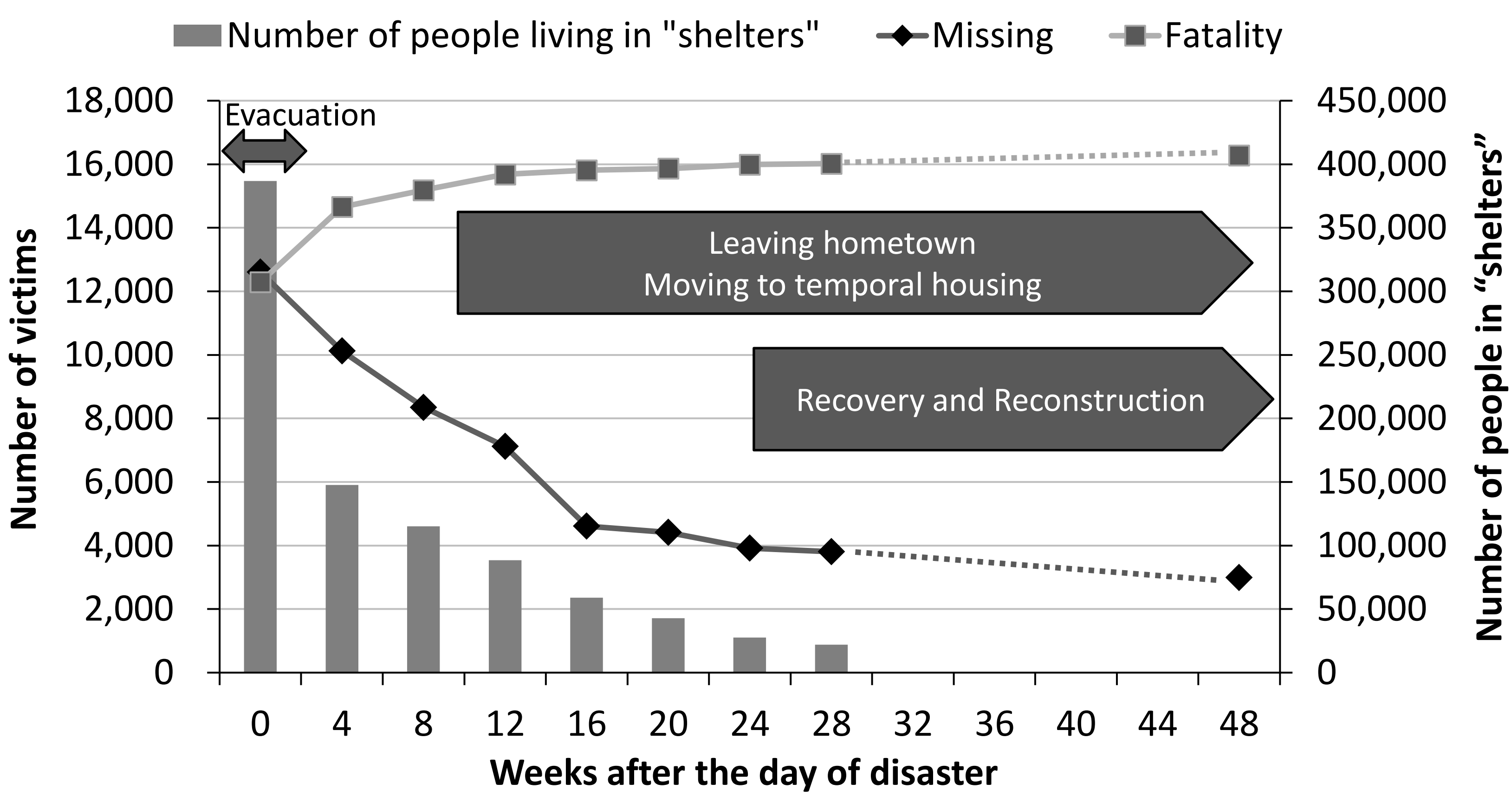
A. Tsunami-affected prefectures (5 prefectures)

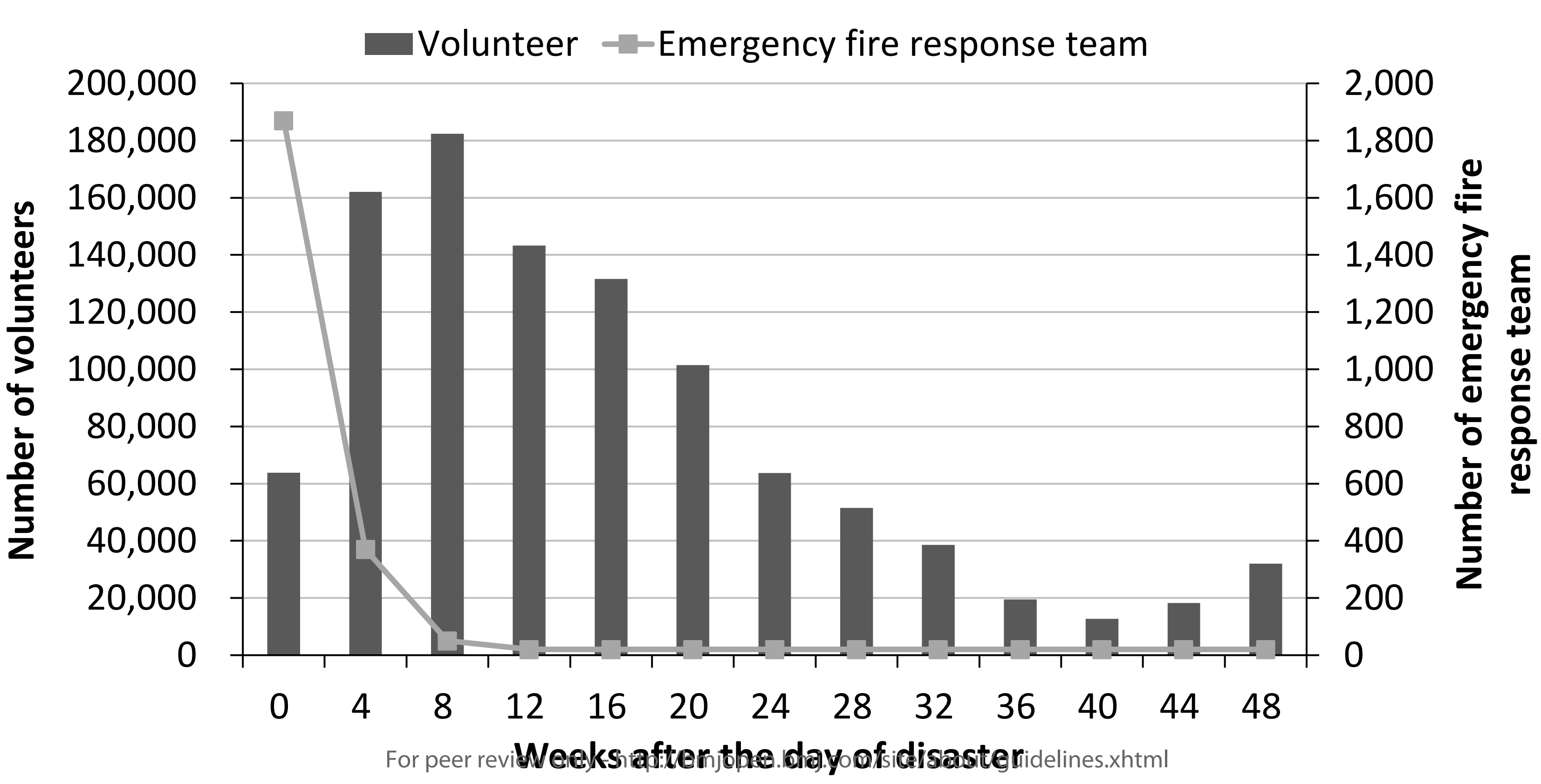


B. Other prefectures (42 prefectures)




Major aftershock
with tsunami warning
Number of aftershock
(Mw>6.0 quakes)
100
80
60
40
20
0
73
9
0
4
3
5
3
0
0
1
0
0
1
0
4
8
12
16
20
24
28
32
36
40
44
48
Earthquake, tsunami
& nuclear accidents
Weeks after the day of disaster


Number of people living in "shelters"
Missing
Fatality
Evacuation
Leaving hometown
Moving to temporal housing
Recovery and Reconstruction
Number of victims
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Number of people in "shelters"
0
4
8
12
16
20
24
28
32
36
40
44
48
Weeks after the day of disaster


Volunteer
Emergency fire response team
Number of volunteers
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Number of emergency fire
response team
0
4
8
12
16
20
24
28
32
36
40
44
48
Weeks after the day of disaster

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Page numbers where the relevant information can be found：page 1	√
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Page numbers where the relevant information can be found：page 3	√
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Page numbers where the relevant information can be found：page 6	√
Objectives	3	State specific objectives, including any prespecified hypotheses Page numbers where the relevant information can be found：page 7	√
Methods			√
Study design	4	Present key elements of study design early in the paper Page numbers where the relevant information can be found：page 7	√
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Page numbers where the relevant information can be found：page 7	√
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Page numbers where the relevant information can be found：page 7	√
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed Page numbers where the relevant information can be found：non	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Page numbers where the relevant information can be found：page 8	√
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Page numbers where the relevant information can be found：page 8	√
Bias	9	Describe any efforts to address potential sources of bias Page numbers where the relevant information can be found：page 7	√
Study size	10	Explain how the study size was arrived at Page numbers where the relevant information can be found：page 7, Figure 1	√
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Page numbers where the relevant information can be found：page 10	√
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding Page numbers where the relevant information can be found：page 8	√
		(*b*) Describe any methods used to examine subgroups and interactions Page numbers where the relevant information can be found：page 10	√
		(*c*) Explain how missing data were addressed Page numbers where the relevant information can be found：page 7	√
		(*d*) If applicable, explain how loss to follow-up was addressed Page numbers where the relevant information can be found：non	
		(*e*) Describe any sensitivity analyses Page numbers where the relevant information can be found：page 9	√

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed Page numbers where the relevant information can be found：page 11, Figure 1	√
		(b) Give reasons for non-participation at each stage Page numbers where the relevant information can be found：page 7, Figure 1	√
		(c) Consider use of a flow diagram Page numbers where the relevant information can be found：Figure 1	√
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders Page numbers where the relevant information can be found：page 12	√
		(b) Indicate number of participants with missing data for each variable of interest Page numbers where the relevant information can be found：page 7	√
		(c) Summarise follow-up time (eg, average and total amount) Page numbers where the relevant information can be found：page 7	√
Outcome data	15*	Report numbers of outcome events or summary measures over time Page numbers where the relevant information can be found：page 11	√
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Page numbers where the relevant information can be found：page 13	√
		(*b*) Report category boundaries when continuous variables were categorized Page numbers where the relevant information can be found：non	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period Page numbers where the relevant information can be found：non	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Page numbers where the relevant information can be found：page 14	√
Discussion			
Key results	18	Summarise key results with reference to study objectives Page numbers where the relevant information can be found：page 18	√
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Page numbers where the relevant information can be found：page 17	√
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Page numbers where the relevant information can be found：page 14	√
Generalisability	21	Discuss the generalisability (external validity) of the study results Page numbers where the relevant information can be found：page 17	√
Other information			√
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based Page numbers where the relevant information can be found：page 22	√

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.