

BMJ Open Characteristics of pneumonia deaths after an earthquake and tsunami: an ecological study of 5.7 million participants in 131 municipalities, Japan

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To cite: Shibata Y, Ojima T, Tomata Y, *et al*. Characteristics of pneumonia deaths after an earthquake and tsunami: an ecological study of 5.7 million participants in 131 municipalities, Japan. *BMJ Open* 2016;**6**:e009190. doi:10.1136/bmjopen-2015-009190

► Prepublication history for this paper is available online. To view these files please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2015-009190>).

Received 25 June 2015
Accepted 7 December 2015



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ABSTRACT

Objective: On 11 March 2011, the Great East Japan Earthquake struck off Japan. Although some studies showed that the earthquake increased the risk of pneumonia death, no study reported whether and how much a tsunami increased the risk. We examined the risk for pneumonia death after the earthquake/tsunami.

Design: This is an ecological study.

Setting: Data on population and pneumonia deaths obtained from the Vital Statistics 2010 and 2012, National Census 2010 and Basic Resident Register 2010 and 2012 in Japan.

Participants: About 5.7 million participants residing in Miyagi, Iwate and Fukushima Prefectures during 1 year after the disaster were targeted. All municipalities (n=131) were categorised into inland (n=93), that is, the earthquake-impacted area, and coastal types (n=38), that is, the earthquake-impacted and tsunami-impacted area.

Outcome measures: The number of pneumonia deaths per week was totalled from 12 March 2010 to 9 March 2012. The number of observed pneumonia deaths (O) and the sum of the sex and age classes in the observed population multiplied by the sex and age classes of expected pneumonia mortality (E) were calculated. Expected pneumonia mortality was the pneumonia mortality during the year before. Standardised mortality ratios (SMRs) were calculated for pneumonia deaths (O/E), adjusting for sex and age using the indirect method. SMRs were then calculated by coastal and inland municipalities.

Results: 6603 participants died of pneumonia during 1 year after the earthquake. SMRs increased significantly during the 1st–12th weeks. In the 2nd week, SMRs in coastal and inland municipalities were 2.49 (95% CI 2.02 to 7.64) and 1.48 (95% CI 1.24 to 2.61), respectively. SMRs of coastal municipalities were higher than those of inland municipalities.

Conclusions: An earthquake increased the risk of pneumonia death and tsunamis additionally increased the risk.

Strengths and limitations of this study

- This paper presents data from a large population-based ecological study.
- High-validity data, with national statistics covering all death information, were used.
- Earthquake and tsunami for pneumonia risk were analysed in a single article.
- Population movement was not considered.

BACKGROUND

The Great East Japan Earthquake with a magnitude of 9.0 struck off Japan on 11 March 2011, causing unprecedented damage: 19 074 deaths, 2633 missing persons, 6219 injured, 127 361 buildings completely destroyed and 273 268 partially destroyed.¹ The epicentre was approximately 70 km east of the Oshika Peninsula of Miyagi Prefecture and the hypocentre at an underwater depth was 24 km.¹ It was the most powerful earthquake ever recorded to have struck off Japan. The earthquake then caused a large tsunami which reached shore almost immediately, 30 min after the earthquake.¹ The Japan Meteorological Agency reported tsunami heights of more than 10 m.² Miyagi, Iwate and Fukushima Prefectures suffered heavy damage, and 99.4% of the deaths occurred in these three prefectures.¹

Some studies of the Great East Japan Earthquake of 2011 reported that pneumonia occurred after the earthquake.^{3–7} During 3½ months following the earthquake, the incidence of pneumonia hospitalisations increased by 5.7 times.³ The number of patients in one hospital after the earthquake was 3.68/100 000 compared with 0.47/100 000 in a regular year.⁴ However, two major infectious diseases occurred after a tsunami: wound infection and aspiration pneumonia.⁸ Several

clinical reports showed that tsunami survivors suffered from pneumonia.^{9–12} Tsunami survivors aspirate water, as well as solid matter and dust. A tsunami reportedly hit an area where *Burkholderia pseudomallei* is endemic,⁹ and *Escherichia coli* and *Legionella* pneumonia have been rarely seen in a community-acquired pneumonia.^{10 11 13} Severe pneumonia associated with aspiration of tsunami was known as ‘tsunami lung’.^{12 14}

The risk of pneumonia death was increased by the earthquake and tsunami, respectively. However, it is unclear whether and how much a tsunami increased the risk of pneumonia death. It is important for emergency medicine to make the matter clear, because an earthquake with tsunami causes catastrophic damage and the medical staff must use limited medical resources effectively. Hence, the aim of the present study was to determine the risk for pneumonia death after the earthquake/tsunami.

METHODS

Study population

This is an ecological study in Japan. Data from the 131 municipalities (population about 5.7 million) in Japan 2010–2012 were used. All participants residing in Miyagi, Iwate and Fukushima Prefectures were examined, including their 131 municipalities, both coastal (n=38) and inland (n=93) (figure 1).

Data sources

The Vital Statistics 2010–2012, National Census 2010 and Basic Resident Register 2010–2012 in Japan were

used. Death data from Vital Statistics were obtained from public health centres in prefectures, which then sent the data to the Ministry of Health, Labour and Welfare. Data collection by public health centres was temporarily suspended owing to earthquakes, but public health centres acquired all data and sent them to the respective prefecture by June 2011. We defined pneumonia death using the International Classification of Diseases (ICD) 10. ‘Pneumonia’ was defined as J12 to J18. Our study classification did not include ‘Exposure to forces of nature (X30 to X39),’ including ‘Victim of earthquake (X34)’. Data on pneumonia deaths were obtained during 1 year before and after the earthquake.

The population data were obtained from the Basic Resident Register and National Census. The Basic Resident Register was maintained by municipalities and reported every month. The weekly population was calculated using the linear estimation method. Populations from the Basic Resident Register were categorised in 17 age classes (0–4 to 80+ age class). The National Census is taken every 5 years; the latest is the 2010 version. Populations from the National Census were categorised into 18 age classes (0–4 to 85+ age class). We allocated the 80+ age class to the 80–84 and 85+ age class. The same proportional distribution was maintained in the National Census.

Statistics

Standardised mortality ratios (SMRs) were calculated to show how many times larger the pneumonia mortality is

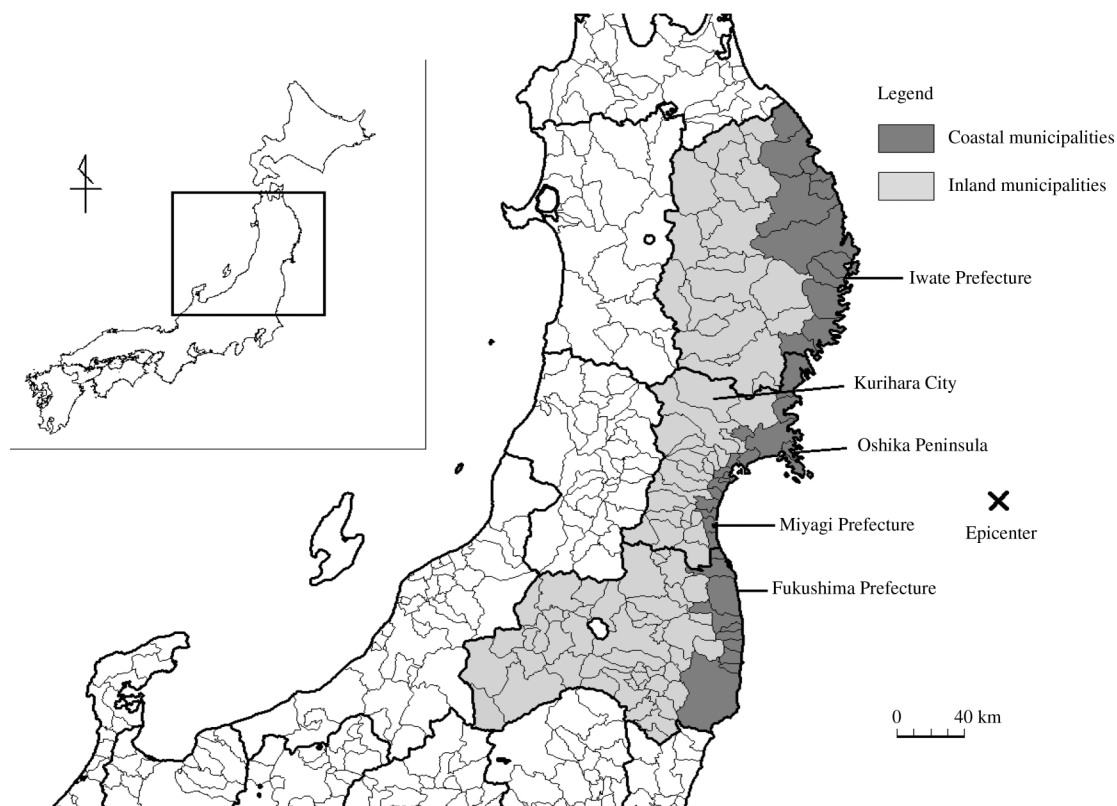


Figure 1 Location of Iwate, Miyagi and Fukushima Prefectures and epicentre of the Great East Japan Earthquake.

compared to that of 1 year before adjusting for sex and age.¹⁵ In detail, the sex-specific and age-specific pneumonia mortality before the earthquake (pre-52nd to pre-1st weeks, standard period) was multiplied by the sex-specific and age-specific population after the earthquake (post-1st to post-52nd weeks, comparison period) to obtain the products by week. The total of the products were calculated to obtain the expected number of pneumonia deaths (E). The total number of observed pneumonia deaths (O) was calculated. SMRs were obtained by O divided by E. The 95% CIs of SMRs were estimated using the Poisson distribution. SMRs were calculated for all municipalities and were additionally calculated for coastal and inland municipalities as one group. All analyses were performed with the SAS V.9.3 (SAS, Institute, Cary, North Carolina, USA).

RESULTS

Characteristics of population

In the three prefectures aforementioned, 6603 participants died of pneumonia during the year after the earthquake, and 5776 participants during the year before (table 1). A total of 4488 participants died of pneumonia during 1 year after in inland municipalities and 4016 participants died during 1 year before. In coastal municipalities, a total of 2115 participants died of pneumonia during 1 year after and 1760 participants died during 1 year before (table 1).

Trend of pneumonia deaths and SMRs for pneumonia deaths

The number of pneumonia deaths increased after the earthquake (figure 2). In inland municipalities, pneumonia deaths were <100 before the earthquake and increased to 120 after it. In coastal municipalities, although pneumonia deaths were fewer than 50 before the earthquake, the number increased to 90 after it. The number of pneumonia deaths in the three prefectures increased after the earthquake. The ratio of the number of pneumonia deaths 1 year after to that of 1 year before was 1.14.

The SMRs for pneumonia death increased during the 1st–12th weeks after the earthquake (table 2). The numbers of expected deaths, observed deaths and excess deaths during the 1st–12th weeks were 602, 1072 and 470, respectively. The highest SMR was 1.78 (95% CI 1.56 to 3.64) in the 2nd week. During the 2nd–5th weeks, SMRs showed a relatively high level, but they steadily decreased by the 12th week.

SMRs in coastal municipalities were higher than in inland municipalities. The SMRs in the 2nd week in coastal and inland municipalities were 2.49 (95% CI 2.02 to 7.64) and 1.48 (95% CI 1.24 to 2.61), respectively (figure 2 and table 2).

DISCUSSION

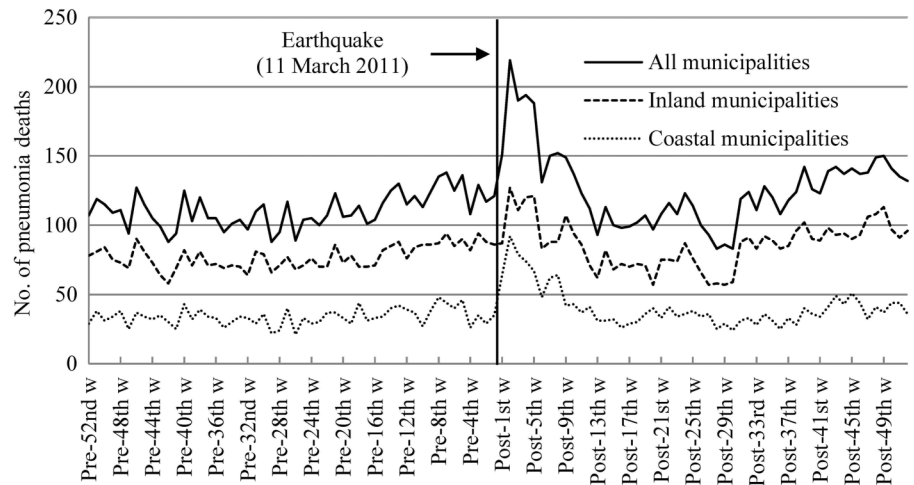
In this study, the risk during the 2nd–4th weeks was about twofold in the coastal municipalities. A significantly increased risk of pneumonia death occurred during the 1st–12th weeks after the Great East Japan Earthquake. To the best of our knowledge, this is the first study to report that the risk of pneumonia death was additionally increased in coastal municipalities.

Our study showed that association between disaster and pneumonia death. In the South Asian Earthquake of 2005, mobile clinics documented that infectious diseases accounted for at least 65% of all illness.¹⁶ The following surveillance also showed that acute respiratory infection, including pneumonia, continued to be the most common cause of clinic visits. In the Hanshin-Awaji Earthquake, the proportion of patients with respiratory infection was more than half of all infectious diseases.¹⁷ Previous studies suggested that several factors have contributed to pneumonia death, although the causal mechanism was not fully established.^{3 4 18 19} Lack of appropriate nutrition, loss of regular medicines, psychological stress and cold temperature might increase the risk of pneumonia death.^{3 4 18 19} Additionally, the accident at the atomic power plant in Fukushima Prefecture forced residents to evacuate their living area. It led to a high population density in the shelter and might have increased the risk of pneumonia death. Generally, the

Table 1 Characteristics of the population in Miyagi, Iwate and Fukushima Prefectures in coastal and inland municipalities

Characteristics	All municipalities	Coastal municipalities	Inland municipalities
Population	5 725 977	1 801 324	3 924 653
Sex			
Female (%)	2 948 873 (51.5)	925 551 (51.4)	2 023 322 (51.6)
Male (%)	2 777 104 (48.5)	875 773 (48.6)	1 901 331 (48.4)
Age, years			
–14 (%)	766 815 (13.4)	241 192 (13.4)	525 623 (13.4)
15–64 (%)	3 579 121 (62.5)	1 123 719 (62.4)	2 455 402 (62.6)
65+ (%)	1 380 041 (24.1)	436 413 (24.2)	943 628 (24.0)
Pneumonia deaths			
N			
One year before	5 776	1760	4016
One year after	6 603	2115	4488

Figure 2 Number of pneumonia deaths during 1 year before and after the earthquake.



risk of pneumonia death in elderly people was higher than that in young people. The ageing rate of 24.1% might have also contributed to this outbreak.

Our study showed that SMRs of coastal municipalities were higher than for inland municipalities, although the highest seismic intensity area for the earthquake was Kurihara City, an inland municipality. These findings revealed that a tsunami might increase the pneumonia death risk in addition to the effects of the earthquake. We propose two hypotheses: first, tsunami lung, which involves aspiration of the tsunami, increased the pneumonia death risk,^{12 14 20} and second, a tsunami-impacted area was more damaging than an earthquake-impacted one. A tsunami raised more dust. Previous studies indicated that the number of hospitalised patients with pneumonia was related to destruction ratios,²¹ and showed that the higher

percentage of households flooded was associated with a higher risk of indirect mortality.²² Many tsunami survivors lost their homes and had to flee to shelters in the destroyed environment. The medical staff were not stationed in all shelters. The tsunami also destroyed transport infrastructure such as roads and railway systems. Tsunami survivors could thus not go to the hospital and obtain sufficient medical care. However, only one study reported that a tsunami did not increase the risk of infections in Sri Lanka in 2004,²³ for example. The different results were caused by several factors. The proportion of people 65 years or older in Sri Lanka is less than that of Japan.²⁴ Sri Lanka has a tropical climate with warm temperature, and death information was obtained from householders.

Our study has several strengths. First, we analysed both the earthquake and tsunami for risk of pneumonia

Table 2 Standardised mortality ratios (SMRs) for pneumonia compared with 1 year before

Earthquake (11 March 2011)	All municipalities		Coastal municipalities		Inland municipalities	
	SMRs	(95% CI)	SMRs	(95% CI)	SMRs	(95% CI)
1st week	1.37	(1.16 to 2.20)	1.93	(1.50 to 4.77)	1.13	(0.91 to 1.58)
2nd week	1.78	(1.56 to 3.64)	2.49	(2.02 to 7.64)	1.48	(1.24 to 2.61)
3rd week	1.60	(1.38 to 2.96)	2.20	(1.76 to 6.09)	1.34	(1.11 to 2.17)
4th week	1.72	(1.49 to 3.43)	2.19	(1.73 to 6.05)	1.52	(1.27 to 2.79)
5th week	1.65	(1.42 to 3.13)	1.95	(1.52 to 4.87)	1.51	(1.26 to 2.75)
6th week	1.35	(1.13 to 2.18)	1.65	(1.23 to 3.64)	1.22	(0.98 to 1.87)
7th week	1.15	(0.97 to 1.55)	1.58	(1.22 to 3.22)	0.96	(0.77 to 1.14)
8th week	1.28	(1.09 to 1.94)	1.80	(1.40 to 4.18)	1.06	(0.86 to 1.39)
9th week	1.38	(1.17 to 2.25)	1.30	(0.95 to 2.29)	1.42	(1.17 to 2.45)
10th week	1.35	(1.14 to 2.17)	1.40	(1.03 to 2.67)	1.33	(1.08 to 2.18)
11th week	1.36	(1.13 to 2.20)	1.36	(0.97 to 2.58)	1.35	(1.09 to 2.27)
12th week	1.16	(0.96 to 1.62)	1.41	(1.03 to 2.73)	1.05	(0.83 to 1.40)
13th week	0.73	(0.59 to 0.65)	0.81	(0.56 to 0.93)	0.69	(0.53 to 0.62)
14th week	1.07	(0.88 to 1.37)	0.98	(0.67 to 1.37)	1.10	(0.88 to 1.52)
15th week	0.81	(0.66 to 0.80)	0.86	(0.60 to 1.07)	0.79	(0.62 to 0.79)
16th week	0.91	(0.74 to 1.00)	0.80	(0.54 to 0.96)	0.95	(0.75 to 1.14)
17th week	0.92	(0.75 to 1.04)	0.90	(0.61 to 1.17)	0.93	(0.73 to 1.10)
18th week	1.05	(0.86 to 1.34)	1.02	(0.70 to 1.51)	1.06	(0.83 to 1.42)
19th week	1.04	(0.85 to 1.30)	1.16	(0.82 to 1.88)	0.98	(0.77 to 1.23)
20th week	0.91	(0.74 to 1.01)	1.25	(0.90 to 2.15)	0.76	(0.58 to 0.76)

death in a single article. No study to date has examined the relationship between some natural disasters and pneumonia death risk in a single article. Our results showed that tsunami survivors need intensive care and prevention for pneumonia death. Second, we used large population-based data. Previous studies were reported from some hospitals or clinics, but did not include participants who died of pneumonia at home and shelters. Finally, we used high validity data, with national statistics covering all death information.

However, our study has some limitations. First, it classified coastal municipalities as tsunami-impacted areas. It was difficult to classify areas into tsunami-impacted areas accurately. Therefore, coastal municipalities include some areas with no tsunami damage. This leads to underestimation of the tsunami effects on the risk of pneumonia death. Second, population movement was not considered. Some people must have evacuated from coastal municipalities to inland municipalities or inland areas of the same municipalities. Therefore, the number of pneumonia deaths must have been higher in inland areas than in coastal areas. This also leads to an underestimation of tsunami effects on the risk of pneumonia death.

CONCLUSION

Our study showed that a tsunami additionally increased the risk of pneumonia death. Our observations underscore the need for emergency preparedness for pneumonia.²⁵

Contributors YS, TO, MK and SH contributed to the study conception/design. MK and SH contributed to the data collection. YS, TO and SH conducted the data analysis. YS drafted the article. TO, YT, EO, MN, MK and SH revised the article and reviewed the draft of the article.

Funding This work was supported by Health Sciences Research Grants (H24-Toukei-Ippan-006, H25-Kenki-Shitei-002 [fukkou]) from the Ministry of Health, Labour and Welfare of Japan.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Additional data can be accessed via the Dryad data repository at <http://datadryad.org/> with the doi:10.5061/dryad.1k01d.

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