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## Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes

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# Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes

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1 39 **Abstract**

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4 40 **Objectives:** Earthquakes are distressing natural phenomena that can potentially disrupt normal health  
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6 41 behaviors. The aim of this study was to investigate changes in alcohol consumption behaviors in the  
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9 42 immediate aftermath of mild to moderate earthquakes.

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12 43 **Setting:** This retrospective cohort study conducted at a large academic hospital in Tokyo, Japan, from April  
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15 44 2004 to March 2017.

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18 45 **Participants:** We included all adult patients presenting to the emergency room with acute alcohol  
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21 46 intoxication.

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24 47 **Primary and secondary outcome measures:** Our outcome was the number of such patients per 24-hour  
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27 48 period, comparing days with and without earthquake activity. We conducted simple generalized  
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30 49 autoregressive conditional heteroscedasticity (GARCH) analysis, followed by multivariate GARCH  
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33 50 including year-fixed effects and secular changes in alcohol taxation. Subanalyses were conducted by gender  
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36 51 and age group.

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38 52 **Results:** During the study period, 706 earthquakes were observed with median magnitude of 5.2 (SD: 1.0).

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41 53 During this period, 6,395 patients were admitted with acute ethanol intoxication; mean age was 42.6 (SD:

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44 54 16.9) years and 4,592 (71.8%) were male. In univariate analyses, daytime earthquake was marginally

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47 55 inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01).

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49  
50 56 This finding remained similar in multivariate analyses after adjustment for covariates. In analyses stratified

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53 57 by gender, the inverse association between daytime earthquake and alcohol intoxication was only observed

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56 58 among men ( $p < 0.03$  for male and  $p = 0.99$  for female). In subanalyses by age, older people were less likely to

1 59 be admitted to the hospital due to acute alcohol intoxication on days with daytime earthquakes ( $p=0.11$ ), but  
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4 60 not younger people ( $p=0.36$ ).  
5

6 61 **Conclusion:** On days when a mild to moderate daytime earthquake occurred, the number of patients with  
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9 62 acute alcohol intoxication was lower compared to days without earthquakes. Even milder forms of  
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12 63 potentially catastrophic events appear to influence social behavior; mild to moderate earthquake activity is  
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15 64 associated with avoidance of excessive alcohol consumption.  
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23 67 *Article summary*  
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25  
26 68 Strengths and limitations of this study  
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28 69 • This is the first and quite unique study which evaluated alcohol consumption behavior immediate aftermath  
29 70 earthquakes.

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31 71 • Robust analyses supported the findings in this study.

32 72 • The limitation of this study was that single center with single ethnicity.  
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## 74 **Introduction**

75 Catastrophic earthquake activity has been reported to exert a variety of effects on both physical as  
76 well as mental health<sup>1</sup>. A previous study reported that approximately 42.6% of victims exhibited moderate  
77 to serious mental health problems after the Great East Japan earthquake, which occurred in March 2011<sup>1</sup>.  
78 Acute health effects associated with experience of earthquake activity include acute stress disorders<sup>2</sup>,  
79 delirium,<sup>3</sup> as well as acute and transient psychotic disorders. Longer term effects on victims' well-being  
80 have also been reported, including post-traumatic stress disorder and exacerbation of bipolar disorder<sup>4-6</sup>.  
81 Although the majority of previous research has been limited to the health impacts of rare catastrophic  
82 earthquakes, very few studies have focused on the health effects associated with substantially more common  
83 mild to moderate earthquakes.

84 Substance abuse is a common disorder reported in the setting of catastrophic disasters<sup>7,8</sup>. Several  
85 studies have explored this relationship with regard to alcohol use behaviors<sup>9,10</sup>, with several previous studies  
86 reporting an increased prevalence of alcohol abuse after major earthquakes.<sup>11,12</sup> However, in the larger  
87 context of catastrophic phenomena this association remains unclear, with one report showing only a 2%  
88 increase in prevalence after a major hurricane<sup>13</sup> and other studies reporting a slight decrease in alcohol  
89 abuse after instances of terrorism<sup>9,14</sup>. As such, the effect of disasters on alcohol abuse remains controversial.  
90 Previous studies have suggested gender, age, education, and even cultural background modify these  
91 associations.<sup>15,16</sup>

92 Japan is a tectonically-active country where earthquakes are observed frequently. The Japan  
93 Meteorological Agency observed 2,025 earthquakes in 2017 and more than 6,500 earthquakes were  
94 observed in 2016 in Japan<sup>17</sup>. Among the, 76 (3.8%) in 2017 and 123 (1.9%) in 2016 of earthquakes were

1 95 more than magnitude of 5. In addition to incidence of earthquakes, the Japan Meteorological Agency also  
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4 96 recorded the date and time, magnitude, location, and seismic intensity<sup>18</sup>. Thus, the aim of this study was to  
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6 97 evaluate the same-day association between mild to moderate earthquakes and unhealthy alcohol use  
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9 98 behavior in Japan.  
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1 99 **Methods**

4 100 *Cohort description*

7 101 *Patient and Public Involvement*

10 102 We conducted a retrospective daily time series study using medical records data from St. Luke's  
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13 103 International Hospital, Tokyo, Japan from April 2004 to March 2017. We included all adult patients  
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15 104 presenting to the hospital emergency room with acute alcohol intoxication. We excluded all patients who  
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18 105 signed opt out agreements for their anonymized data to be used in research. In addition, patients presenting  
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21 106 with altered mental status of uncertain origin were excluded. Our outcome was patient volume of acutely  
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24 107 intoxicated patients per 24-hour period. Outcomes were compared between days with and without  
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27 108 earthquakes, as observed by the Japan Meteorological Agency. The ethical committee at St. Luke's  
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30 109 International Hospital approved this study (approval number: 17-R025). In terms of data sharing, no  
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33 110 additional patients' data were available, although data about earthquakes were available on the website of  
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35 111 Japan Meteorological Agency<sup>17</sup>. This study was totally authors' own work and there was no funding to  
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38 112 support this study. The results of this study will be disseminated through publication and will not be noticed  
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41 113 to each participant because this was a retrospective design.

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47 115 *Acute alcohol intoxication*

50 116 The diagnosis of acute alcohol intoxication was made clinically based on testimony by patients or  
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53 117 their companions. Blood ethanol level of 100 mg/dl or higher was used to support the diagnosis for those in  
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56 118 whom testimony could not be elicited directly<sup>19</sup>.

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## 120 *Earthquake*

121 All earthquake data was obtained from the Japan Meteorological Agency<sup>17</sup>. Recorded data contains  
122 time and date of occurrence, the Richter magnitude, the depth of epicentre, and Shindo scale data for any  
123 earthquake sensed. With a range of 0 to 7, Shindo is the unique measurement scale used in Japan for seismic  
124 intensities in a specific area<sup>18</sup>. Unlike the Richter scale, which represents the size of earthquake itself and is  
125 unique for each earthquake, Shindo scaling reflects intensity of observed shaking in a given area, and is  
126 based on distance from epicenter at which the seismic activity was observed. Generally speaking, the further  
127 the observed area is from the epicenter, the lower the Shindo measurement is for that area. A Shindo score  
128 of 1 is comparable to mild sense of shaking observed only when sitting quietly in a structure, while a Shindo  
129 score of 4 is defined as observable shaking enough to cause startle, awakenings from sleep, and which may  
130 be felt while walking. A Shindo score of 7 equates to severe shaking in which it is impossible to remain  
131 standing or to move without crawling. We defined daytime earthquake as those observed between 9 a.m. to  
132 5 p.m., while night time earthquake was defined as occurring between 5 p.m. to 12 a.m.

## 134 *Study site*

135 St. Luke's International Hospital is located in Chuo-ku, Tokyo, Japan. The hospital, a 520-bed  
136 tertiary-level community teaching hospital, accepts more than 10,000 ambulance admissions a year. Located  
137 close to Ginza, a major entertainment district popular for bars and restaurants serving alcohol, St. Luke's  
138 receives the largest number of ambulances per year, including approximately 50% of ambulances dispatched  
139 from the Ginza area. We included only earthquakes which were observed in this metropolitan Tokyo area in  
140 the analyses.

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4 142 *Category of day in relation to work week and seasonality*

7 143 Because the incidence of acute alcohol intoxication is considered to vary substantially by day of the  
10 144 week, we divided days into three categories: weekdays, the day prior to a non-working day, and  
13 145 non-working day (generally understood in Japan to be Saturday, Sunday, and designated national holidays).  
15 146 For days overlapping categories, we considered the day prior to a non-working day was most dominant. For  
18 147 instance, as January 1st, 2nd, and 3rd are designated national holidays in Japan, we categorized January 1st  
21 148 and 2nd as days prior to non-working day, and 3rd as a non-working day.

24 149 As the incidence of acute alcohol intoxication is also considered to be related to seasonality, we  
27 150 categorized March, April and May into spring; June, July and August into summer; September, October and  
30 151 November into fall; December, January and February into winter.

33 152

36 153 *Statistical analyses*

39 154 Because the occurrence of earthquakes on a certain day was considered to be autocorrelated and  
42 155 have autoregressive conditional heteroscedasticity (ARCH) effect (Figure), we applied multivariate  
44 156 generalized autoregressive conditional heteroscedasticity (GARCH) approach with dynamic conditional  
47 157 correlation to investigate the association between patient presentation to the ER with acute alcohol  
50 158 intoxication and occurrence of earthquakes<sup>20-22</sup>. In terms of primary outcome, we first applied a simple  
53 159 GARCH model with each variable examining the relationship between hospital admission for acute alcohol  
56 160 intoxication and earthquake activity, category of day, and seasonality. This was followed by a multivariate  
58 161 GARCH(1,1) model performed with variables found to have *p* value of 0.2 or lower in the simple GARCH

1 162 model, as well as year-fixed effect and changes in alcohol taxation.  $\beta$  coefficient and 95% confidence  
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4 163 intervals (CI) were calculated. In addition, we stratified the analyses by both gender and age (50 years or  
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6 164 older versus less than 50 years). Moreover, we separately analyzed data before the Great East Japan  
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9 165 earthquake on March 11, 2011 and after the earthquake. We also conducted sensitivity analyses to check  
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12 166 robustness with the following three methods: including Richter scale magnitude as covariate to evaluate  
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15 167 whether the results differ according to magnitude of the earthquake; introducing different lag times between  
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18 168 the earthquake and hospital visits(e.g. 1, 3 or 7 days later from earthquakes); excluding days in which severe  
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21 169 earthquakes (Shindo scale  $\geq 4$ ) occurred. All analyses were performed using Stata 14.0 (Stata Corp, TX,  
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23 170 USA).

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## 172 **Results**

173 During the study period, earthquakes were observed 706 times with median Shindo score in the  
174 catchment area of 2 (Interquartile range 1). During the 4,747 days in the study period, earthquakes were  
175 observed on 500 days. During this period, 6,395 patients were treated with acute ethanol intoxication with  
176 mean age of 42.6 (*SD* 16.9); 4,592 (71.8%) were male.

177 Table 1 shows the results for number of patients with acute ethanol intoxication from the simple  
178 and multivariate GRACH models. In univariate analyses, daytime earthquake was marginally and inversely  
179 related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01). Days prior  
180 to a non-working day ( $\beta$  coefficient: 0.26, 95%CI: 0.15 - 0.37) was significantly and non-working days ( $\beta$   
181 coefficient: 0.08, 95%CI: -0.01 - 0.14) was marginally significantly related to acute intoxication. These  
182 findings remained similar in multivariate analyses after adjusting for both occurrence of a daytime  
183 earthquake, category of day, seasonality, year-fixed effect and change in alcohol taxation.

184 In sensitivity analysis, including Richter scale magnitude as a covariate to evaluate whether the  
185 results differ according to magnitude of the earthquake, daytime earthquake was still marginally related to  
186 decreased patient volume ( $\beta$  coefficient: -0.23, 95% CI: -0.47 - 0.01). However, the magnitude of earthquake  
187 itself had no relation with patient volume ( $\beta$  coefficient: 0.01, 95% CI: -0.02 - 0.04). When we introduced  
188 different lag times between the earthquake and hospital visits, daytime earthquake was also marginally  
189 related to decreased patient volume significantly ( $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.01 for 1 day later  
190 from earthquake;  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 3 days later from earthquake; and  $\beta$   
191 coefficient: -0.18, 95% CI: -0.38 - 0.02 for 7 day later from earthquake), while different lag times  
192 themselves were not associated with patient volume. When we excluded days in which severe earthquakes

1 193 (Shindo scale  $\geq 4$ ) occurred, findings were similar [daytime earthquake ( $\beta$  coefficient: -0.18, 95% CI: -0.38 -  
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4 194 0.02)].

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6 195 Table 2 shows the result for the number of patients with alcohol intoxication from univariate and  
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9 196 multivariate analyses stratified by gender. The inverse association between daytime earthquake and alcohol  
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12 197 intoxication seen in pooled analysis was only observed among men ( $p < 0.03$  for male and  $p = 0.99$  for female).  
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15 198 Although a positive association between the day before non-working days and acute alcohol intoxication  
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18 199 were observed in both males ( $p < 0.01$ ) and females ( $p < 0.01$ ), higher rates of intoxication on non-working  
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21 200 days was only observed in women ( $p = 0.02$  for female and  $p = 0.35$  for male). Among male patients, the  
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24 201 number of patients with acute alcohol intoxication rose during winter compared to spring ( $p = 0.01$ ), but not  
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26 202 among females ( $p = 0.42$ ).

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29 203 Table 3 shows the result for the number of patients with alcohol intoxication from univariate and  
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32 204 multivariate analyses stratified by age group. Older people were less likely to be admitted to ER due to acute  
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35 205 alcohol intoxication on days when daytime earthquakes occurred ( $p = 0.11$ ), but the same pattern was not  
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38 206 seen among younger people ( $p = 0.36$ ). Both older and younger patients with acute alcohol intoxication were  
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41 207 more likely to be admitted on the days before non-working days, as well as on non-working days compared  
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43 208 to weekdays. However, in terms of seasonality, older people were significantly more likely to be admitted to  
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46 209 the ER with acute alcohol intoxication in the winter season ( $p < 0.01$ ), but not younger people ( $p = 0.83$ )

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49 210 In terms of stratification by the date of the Great East Japan earthquake, daytime earthquake was  
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52 211 inversely related to the number of acutely intoxicated patients after the Great East Japan earthquake ( $\beta$   
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55 212 coefficient: -0.28, 95% CI: -0.55 - -0.02), while daytime earthquake was not related before the Great East  
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57 213 Japan earthquake ( $\beta$  coefficient: -0.02, 95% CI: -0.32 - 0.29).

## Discussion

Our study found several predictors of the number of intoxicated patients presenting to the ER of a major urban hospital in Japan. Notably, there was an inverse relationship between the number of intoxicated patients and daytime earthquakes observed in older patients and men.

Although previous studies that evaluated drinking behavior after catastrophic earthquakes reported both positive and negative effects, we found that non-catastrophic earthquakes may exert a dampening (i.e. a health-favorable) effect on excess alcohol consumption. This finding was considered to be a kind of stress-related growth, which is the theory that people grow from negative events<sup>23</sup>. We speculate that people may avoid risky behaviors, such as going out with companions after work to indulge in excessive amounts of drinking, immediately after an earthquake. When people experience earthquakes, many may suspect additional tectonic activity; multiple earthquakes in a single day are common and were observed on 83 (16.7%) days in our study. As a result, we suspect that many people choose to go home rather than go out, as has been documented in reports about catastrophic earthquakes<sup>24</sup>. People may avoid social activities, such as after-work gatherings, on days in which even mild, but nevertheless frightening, natural phenomena has occurred, thereby lowering the opportunities for excessive drinking and other risky social behaviors. Lower blood alcohol levels noted on earthquake days also suggests that even imbibers may limit the amount of alcohol consumed on such days. Similar social behaviors have been observed after the Great East Japan earthquake in 2011, though whether these behavioral changes are conscious or unconscious remains unclear<sup>25</sup>.

We found both age and gender differences in the relationship between daytime earthquakes and acute alcohol intoxication. There were statistically fewer male patients with acute alcohol intoxication on

1 235 days when a daytime earthquake occurred compared to days without seismic activity. Interestingly, this  
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4 236 relationship was not found for female patients. A previous systematic review reported differing patterns of  
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6 237 alcohol use between men and women are driven by both biological and psycho-socio-cultural factors<sup>26</sup>. As a  
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9 238 result, men are more likely to seek sensation, including hazardous drinking, than women in ordinal settings  
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12 239<sup>27,28</sup>. However, it is possible that mild earthquakes may affect these psycho-socio-cultural factors more for  
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15 240 men than women. Social capital may play an important role for this<sup>29</sup>. Because most Japanese male workers  
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18 241 drink with colleagues after work<sup>30</sup>, some may suggest others not to go out for drinking after work on the  
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21 242 day with earthquakes.

23 243 In terms of age, fewer older patients with acute alcohol intoxication were observed on days with  
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26 244 earthquakes, despite an unchanged number of younger patients presenting with acute alcohol intoxication on  
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29 245 these days. A previous surveys about alcohol use reported that younger people tended to have more binge  
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32 246 drinking and heavy episodic drinking not only in Japan<sup>31</sup>, but also other countries<sup>32</sup>. Psychologically  
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35 247 disturbing natural phenomenon, however mild, may also exert specific inhibitory psycho-socio-cultural  
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38 248 effects on risky behaviors of younger people. Further research is needed to evaluate the potential  
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41 249 mechanisms for these differences.

43 250 Significantly fewer patients with acute alcohol intoxication were observed on days with daytime  
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46 251 earthquakes compared to that on days without daytime earthquakes after the date of the Great East Japan  
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49 252 earthquake, while the finding was not observed before the date of the Great East Japan earthquake. This  
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52 253 suggests that people still have catastrophic earthquake in their mind and avoid sensation seeking from  
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55 254 stress-related growth.

1 255 Our study has some limitations. First, not all potential patients with acute alcohol intoxication  
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4 256 were transferred to our hospital, resulting in a measure of selection bias. However, as our hospital has the  
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6 257 largest number and highest rate of ambulance acceptances in Tokyo, with more than 50% of ambulances  
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9 258 dispatched to the local entertainment area were transferred to us, we assume that this bias is neither large nor  
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12 259 differential. In addition, the findings may not be applied to other countries, because ethnicity and cultural  
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15 260 diversity could exist<sup>33</sup>. Second, as we were unable to accurately record information about when patients  
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18 261 started to consume alcohol, a precise knowledge of the temporal relationship between alcohol consumption,  
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21 262 intoxication, and earthquakes is difficult to assess. Similarly, as qualitative data concerning patients`  
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24 263 physical and emotional perception of seismic activity is not available, further studies are warranted in this  
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26 264 area. In addition, the evaluation for acute stress disorder may be useful to explain gender and age difference  
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29 265 of findings.

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1 267 **Conclusion**

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4 268 On days when mild to moderate daytime earthquakes occurred, our hospital experienced fewer  
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6 269 number of patients with acute alcohol intoxication presenting to the emergency room. This pattern was also  
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9 270 seen for men and elderly patients. Even mild natural phenomena may lead to changes in social behavior that  
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12 271 result in avoidance of excessive alcohol use.  
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Variable	Univariate GARCH* model			Multivariate GARCH* model		
	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value
Earthquake factors						
Incidence of earthquake	0.00	(-0.12 — 0.12)	0.95			
Number of earthquake a day, times	-0.02	(-0.06 — 0.03)	0.46			
The depth of epicenter, km	0.00	(-0.01 — 0.01)	0.85			
The highest magnitude in a day	0.00	(-0.02 — 0.02)	0.98			
The highest shindo in a day	0.00	(-0.08 — 0.07)	0.92			
Daytime earthquake <sup>§</sup>	-0.19	(-0.40 — 0.01)	0.06	-0.18	(-0.38 — 0.02)	0.07
Nighttime earthquake <sup>‡</sup>	0.12	(-0.12 — 0.35)	0.34			
Date						
Categories of day						
Weekday		Reference			Reference	
The day before non-working day	<b>0.26</b>	<b>(0.15 — 0.37)</b>	<b>&lt;0.01</b>	<b>0.25</b>	<b>(0.15 — 0.36)</b>	<b>&lt;0.01</b>
Non-working day	0.08	(-0.01 — 0.17)	0.05	0.08	(-0.01 — 0.16)	0.08
Season						
Spring		Reference			Reference	
Summer	0.02	(-0.09 — 0.13)	0.73	0.02	(-0.09 — 0.12)	0.78
Fall	0.05	(-0.06 — 0.17)	0.35	0.03	(-0.76 — 0.14)	0.55
Winter	0.10	(-0.01 — 0.22)	0.07	<b>0.12</b>	<b>(0.02 — 0.23)</b>	<b>0.02</b>

Table 1.  $\beta$  coefficients for number of patients with acute ethanol intoxication from univariate and multivariate GARCH model

\*GARCH represents generalized autoregressive conditional heteroskedasticity. Multivariate GARCH model was adjusted for variables found to have *p* value of 0.2 or less in simple GARCH model, as well as year-fixed effect and changes in alcohol taxation.; <sup>†</sup>CI represents confidence interval; <sup>§</sup>Daytime earthquake means that earthquake was observed between 9 a.m. to 5 p.m.; <sup>‡</sup>Nighttime earthquake means that earthquake was observed between 5 p.m. to 12 p.m.. Numbers in bold indicate that the *p* value is less than 0.05.

Variable	Male ( <i>n</i> = 4,646)				Female ( <i>n</i> = 1,826)			
	Univariate GARCH*		Multivariate GARCH*		Univariate GARCH*		Multivariate GARCH*	
	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value
Earthquake factors								
Incidence of earthquake	0.00 (-0.11 — 0.10)	0.98			-0.01 (-0.07 — 0.05)	0.86		
Number of earthquake a day, times	-0.01 (-0.05 — 0.02)	0.39			0.00 (-0.02 — 0.02)	0.79		
The depth of epicenter, km	0.00 (-0.00 — 0.00)	0.98			0.00 (-0.01 — 0.01)	0.78		
The highest magnitude in a day	0.00 (-0.02 — 0.02)	0.98			0.00 (-0.01 — 0.01)	0.98		
The highest shindo in a day	-0.01 (-0.07 — 0.05)	0.81			0.00 (-0.03 — 0.04)	0.94		
Daytime earthquake <sup>§</sup>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.02</b>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.03</b>	0.00 (-0.09 — 0.10)	0.95	0.00 (-0.10 — 0.10)	0.99
Nighttime earthquake <sup>‡</sup>	0.05 (-0.14 — 0.25)	0.59			0.05 (-0.07 — 0.16)	0.41		
Date								
Categories of day								
Weekday		Reference				Reference		
The day before non-working day	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>
Non-working day	0.04 (-0.04 — 0.11)	0.34	0.04 (-0.04 — 0.11)	0.35	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>
Season								

1									
2	Spring		Reference				Reference		
3									
4		-0.00		-0.00		0.02		0.02	
5	Summer	(-0.10 — 0.09)	0.93	(-0.10 — 0.09)	0.93	(-0.03 — 0.07)	0.42	(-0.03 — 0.08)	0.37
6									
7		0.02		0.02		0.02		0.01	
8	Fall	(-0.07 — 0.12)	0.63	(-0.08 — 0.11)	0.74	(-0.04 — 0.07)	0.55	(-0.04 — 0.07)	0.58
9									
10		<b>0.12</b>		<b>0.12</b>		-0.02		-0.02	
11	Winter	<b>(0.02 — 0.21)</b>	<b>0.01</b>	<b>(0.02 — 0.21)</b>	<b>0.01</b>	(-0.07 — 0.03)	0.43	(-0.07 — 0.03)	0.42
12									

Table 2.  $\beta$  coefficients for number of patients with acute ethanol intoxication from univariate and multivariate GARCH model by gender

\*GARCH represents generalized autoregressive conditional heteroskedasticity. Multivariate GARCH model was adjusted for variables found to have  $p$  value of 0.2 or less in simple GARCH model, as well as year-fixed effect and changes in alcohol taxation; †CI represents confidence interval; §Daytime earthquake means that earthquake was observed between 9 a.m. to 5 p.m.; ‡Nighttime earthquake means that earthquake was observed between 5 p.m. to 12 p.m..

Numbers in bold indicate that the  $p$  value is less than 0.05.



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Variable	50 years or older (n = 2,202)				Younger than 50 years (n = 4,270)			
	Univariate GARCH*		Multivariate GARCH*		Univariate GARCH*		Multivariate GARCH*	
	$\beta$ coefficient (95%CI <sup>†</sup> )	p value	$\beta$ coefficient (95%CI <sup>†</sup> )	p value	$\beta$ coefficient (95%CI <sup>†</sup> )	p value	$\beta$ coefficient (95%CI <sup>†</sup> )	p value
<b>Earthquake factors</b>								
Incidence of earthquake	-0.03 (-0.10 — 0.04)	0.37			0.03 (-0.07 — 0.13)	0.54		
Number of earthquake a day, times	-0.01 (-0.03 — 0.01)	0.35			0.00 (-0.04 — 0.03)	0.82		
The depth of epicenter, km	0.00 (-0.00 — 0.00)	0.67			0.00 (-0.01 — 0.01)	0.98		
The highest magnitude in a day	-0.01 (-0.02 — 0.01)	0.39			0.01 (-0.01 — 0.03)	0.54		
The highest shindo in a day	-0.02 (-0.06 — 0.02)	0.35			0.02 (-0.04 — 0.08)	0.58		
Daytime earthquake <sup>§</sup>	-0.09 (-0.20 — 0.01)	0.09	-0.09 (-0.19 — 0.02)	0.11	-0.07 (-0.23 — 0.10)	0.39	-0.08 (-0.24 — 0.09)	0.36
Nighttime earthquake <sup>‡</sup>	0.03 (-0.09 — 0.15)	0.65			0.09 (-0.09 — 0.28)	0.32		
<b>Date</b>								
<b>Categories of day</b>								
Weekday		Reference				Reference		
The day before non-working day	<b>0.06</b> (0.01 — 0.12)	<b>0.02</b>	<b>0.06</b> (0.01 — 0.12)	<b>0.03</b>	<b>0.19</b> ( <b>0.11 — 0.28</b> )	<b>&lt;0.01</b>	<b>0.19</b> ( <b>0.11 — 0.28</b> )	<b>&lt;0.01</b>
Non-working day	-0.04 (-0.08 — 0.01)	0.09	-0.04 (-0.09 — 0.01)	0.08	<b>0.11</b> ( <b>0.04 — 0.18</b> )	<b>&lt;0.01</b>	<b>0.11</b> ( <b>0.05 — 0.18</b> )	<b>&lt;0.01</b>
<b>Season</b>								

1									
2	Spring		Reference				Reference		
3									
4		-0.03		-0.03		0.06		0.06	
5	Summer	(-0.09 — 0.02)	0.26	(-0.09 — 0.02)	0.23	(-0.03 — 0.14)	0.20	(-0.03 — 0.15)	0.17
6									
7		0.01		0.01		0.04		0.03	
8	Fall	(-0.05 — 0.07)	0.73	(-0.05 — 0.06)	0.82	(-0.05 — 0.12)	0.40	(-0.05 — 0.12)	0.45
9									
10		<b>0.10</b>		<b>0.10</b>		0.01		0.01	
11	Winter	<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	(-0.08 — 0.10)	0.81	(-0.08 — 0.79)	0.83
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Table 3.  $\beta$  coefficients for number of patients with acute ethanol intoxication from univariate and multivariate GARCH model by age

\*GARCH represents generalized autoregressive conditional heteroskedasticity; †CI represents confidence interval; §Daytime earthquake means that earthquake was observed between 9 a.m. to 5 p.m.; ‡Nighttime earthquake means that earthquake was observed between 5 p.m. to 12 p.m..

Numbers in bold indicate that the p value is less than 0.05.

1 **Figure legend:**

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4 Figure 1. Daily number of earthquake.

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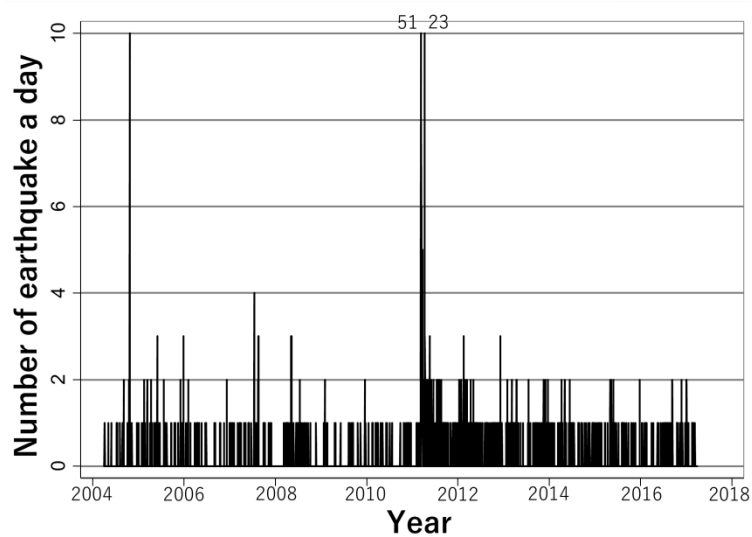


Figure 1. Daily number of earthquake.

279x215mm (300 x 300 DPI)

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

Check	Page, session		Item No	Recommendation
X	Page1. Title	<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
X	Page2-3, abstract			(b) Provide in the abstract an informative and balanced summary of what was done and what was found
<b>Introduction</b>				
X	Page4-5, introduction	Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
X	Page5, last in Introduction	Objectives	3	State specific objectives, including any prespecified hypotheses
<b>Methods</b>				
X	Page6, first paragraph in Methods	Study design	4	Present key elements of study design early in the paper
X	Page6, first paragraph in Methods	Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
X	Page6, first paragraph in Methods	Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
X	Page6, first and second paragraph in Methods			(b) For matched studies, give matching criteria and number of exposed and unexposed
X	Page7-8, third paragraph in Methods	Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
X	Page7-8, third paragraph in Methods	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
X	Page7-8, third paragraph in Methods	Bias	9	Describe any efforts to address potential sources of bias
X	Page9, third paragraph in statistical analyses	Study size	10	Explain how the study size was arrived at
X	Page8, first and second paragraph in statistical analyses	Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

1	X	Page8, first and second paragraph in statistical analyses	Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
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4	X	Page8, first and second paragraph in statistical analyses			(b) Describe any methods used to examine subgroups and interactions
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8	X	Page8, first and second paragraph in statistical analyses			(c) Explain how missing data were addressed
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11	X	N/A			(d) If applicable, explain how loss to follow-up was addressed
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14	X	Page8, first and second paragraph in statistical analyses			(e) Describe any sensitivity analyses
15					
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18			<b>Results</b>		
19	X	Page10, result session	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
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25	X	Page10, result session			(b) Give reasons for non-participation at each stage
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27	X	N/A			(c) Consider use of a flow diagram
28					
29	X	Page10, result session	Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
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33	X	Page10, result session			(b) Indicate number of participants with missing data for each variable of interest
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35	X	Page10, result session			(c) Summarise follow-up time (eg, average and total amount)
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37					
38	X	Page10, result session, table1	Outcome data	15*	Report numbers of outcome events or summary measures over time
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40					
41	X	Page10-11, result session	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
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47	X	Page10-11, result session			(b) Report category boundaries when continuous variables were categorized
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49	X	Page10-11, result session			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
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53	X	Page10-11, result session, Table2.	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
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57			<b>Discussion</b>		
58	X	Page12, first	Key results	18	Summarise key results with reference to
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1				study objectives
2		paragraph in discussion		
3	X	Page 12-14 in discussion	Limitations	19
4				Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
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8	X	Page 14	Interpretation	20
9				Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
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14	X	Page 14	Generalisability	21
15				Discuss the generalisability (external validity) of the study results
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17			<b>Other information</b>	
18	X	Page 1	Funding	22
19				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
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\*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>.

# BMJ Open

## Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes: Time series study

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Secondary Subject Heading:	Addiction
Keywords:	earthquake, alcohol, behavior, alcohol intoxication

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# Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes: Time series study

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## Abstract

**Objectives:** Earthquakes are a distressing natural phenomenon that can disrupt normal health-related behaviors.

The aim of this study was to investigate changes in alcohol consumption behaviors in the immediate aftermath of mild to moderate earthquakes.

**Setting:** This retrospective cohort study was conducted at a large academic hospital in Tokyo, Japan from April 2004 to March 2017.

**Participants:** We included all adult patients presenting with acute alcohol intoxication in the emergency room.

**Primary and secondary outcome measures:** Our outcome was the number of such patients per 24 hour period comparing days with and without earthquake activity. We conducted a simple generalized autoregressive conditional heteroscedasticity (GARCH) analysis, followed by a multivariate GARCH, including year-fixed effects and secular changes in alcohol taxation. Subanalyses were conducted by gender and age group.

**Results:** During the study period, 706 earthquakes were observed with a median magnitude of 5.2 (SD: 1.0).

During this period, 6,395 patients were admitted with acute ethanol intoxication; the mean age was 42.6 (SD:

16.9) years, and 4,592 (71.8%) patients were male. In univariate analyses, the occurrence of daytime

earthquakes was marginally inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19,

95% CI: -0.40 - 0.01). This finding remained similar in multivariate analyses after adjustment for covariates. In

analyses stratified by gender, the inverse association between daytime earthquakes and alcohol intoxication was

only observed among men ( $p < 0.03$  for males and  $p = 0.99$  for females). In subanalyses by age, older people were

less likely to be admitted to the hospital due to acute alcohol intoxication on days with daytime earthquakes ( $p=0.11$ ), but this was not the case for younger people ( $p=0.36$ ).

**Conclusion:** On days when a mild to moderate daytime earthquake occurred, the number of patients with acute alcohol intoxication was lower compared to days without earthquakes. Even milder forms of potentially catastrophic events appear to influence social behavior; mild to moderate earthquake activity is associated with the avoidance of excessive alcohol consumption.

### *Article summary*

#### Strengths and limitations of this study

- This unique study is the first to evaluate alcohol consumption behavior in the immediate aftermath of earthquakes.
- Robust analyses supported the findings in this study.
- The limitation of this study was its analysis of a single center with a single ethnicity.

## Introduction

Catastrophic earthquake activity has been reported to exert a variety of effects on both physical and mental health<sup>1</sup>. A previous study reported that approximately 42.6% of victims exhibited moderate to serious mental health problems after the Great East Japan earthquake, which occurred in March 2011<sup>1</sup>. Acute health effects associated with earthquake activity include acute stress disorders<sup>2</sup>, delirium,<sup>3</sup> and acute and transient psychotic disorders. Longer-term effects on victims' well-being have also been reported, including post-traumatic stress disorder and exacerbation of bipolar disorder<sup>4-6</sup>. Although most previous research has been limited to the health impacts of rare catastrophic earthquakes, very few studies have focused on the health effects associated with substantially more common mild to moderate earthquakes.

Substance abuse is a common disorder reported in the setting of catastrophic disasters<sup>7,8</sup>. Several studies have explored this relationship with regard to alcohol use behaviors<sup>9,10</sup>, with several previous studies reporting an increased prevalence of alcohol abuse after major earthquakes.<sup>11,12</sup> However, in the larger context of catastrophic phenomena, this association remains unclear, with one report showing only a 2% increase in prevalence after a major hurricane<sup>13</sup> and other studies reporting a slight decrease in alcohol abuse after instances of terrorism<sup>9,14</sup>. Moreover, some suggested that disasters have rarely increased the prevalence of substance use disorders. Instead, increased alcohol abuse after disaster can often reflect an exacerbation of existing abuse rather than new onset disorders<sup>15</sup>. As such, the effect of disasters on alcohol abuse remains controversial. Previous studies have suggested that gender, age, education, and even cultural background modify these associations.<sup>16,17</sup>

91 Japan is a tectonically active country where earthquakes are observed frequently. The Japan  
92 Meteorological Agency observed 2,025 earthquakes in 2017, and more than 6,500 earthquakes were observed in  
93 2016 in Japan <sup>18</sup>. Among the 76 earthquakes in 2017 and 123 events in 2016, 3.8% and 1.9%, respectively, were  
94 greater than a magnitude of 5. In addition to the incidence of earthquakes, the Japan Meteorological Agency  
95 recorded the date, time, magnitude, location, and seismic intensity <sup>19</sup>. Thus, the aim of this study was to evaluate  
96 the same-day association between mild to moderate earthquakes and unhealthy alcohol use behavior in Japan.

## Methods

### *Study design and cohort description*

We conducted a retrospective daily time series study using medical record data from St. Luke's International Hospital in Tokyo, Japan from April 2004 to March 2017. We included all patients who were 20 or older and presented to the hospital emergency room with acute alcohol intoxication. We excluded all patients who signed opt-out agreements for their anonymized data to be used in research. In addition, patients presenting with an altered mental status of uncertain origin were excluded. Our outcome was a patient volume of acutely intoxicated patients per 24-hour period. Outcomes were compared between days with and without earthquakes, as observed by the Japan Meteorological Agency. The ethical committee at St. Luke's International Hospital approved this study (approval number: 17-R025).

### *Research ethics application*

In terms of data sharing, no additional patient data were available, although data about earthquakes were available on the Japan Meteorological Agency website<sup>18</sup>. This study was entirely the authors' own work, and no funding supported this study. The results of this study will be disseminated through publication, and individual participants will not be alerted because this was a retrospective design.

### *Acute alcohol intoxication*

Emergency physicians at the hospital clinically diagnosed acute alcohol intoxication based on testimonies by patients or their companions. A blood ethanol level of 100 mg/dl or higher was used to support the diagnosis for those whose testimonies could not be elicited directly<sup>20</sup>.

## Earthquake

All earthquake data were obtained from the Japan Meteorological Agency<sup>18</sup>. The recorded data contain the time and date of occurrence, the Richter magnitude, the depth of epicenter, and Shindo scale data for any earthquake detected. With a range of 0 to 7, Shindo is the unique measurement scale used in Japan for seismic intensities in a specific area<sup>19</sup>. Unlike the Richter scale, which represents the size of the earthquake itself and is unique for each earthquake, Shindo scaling reflects the intensity of the observed shaking in a given area and is based on the distance from the epicenter at which the seismic activity was observed. Generally speaking, the further the observed area is from the epicenter, the lower the Shindo measurement is for that area. A Shindo score of 1 is comparable to mild shaking observed only when sitting quietly in a structure, while a Shindo score of 4 is defined as observable shaking that is intense enough to startle, awaken people from sleep, and can be detected while walking. A Shindo score of 7 equates to severe shaking in which it is impossible to remain standing or move without crawling. In terms of the severity of the earthquake, we defined earthquakes with a Shindo score of 1 – 3 as mild to moderate earthquakes and those with a Shindo score of 4 or more as severe earthquakes. We defined a daytime earthquake as one observed between 9 a.m. and 5 p.m., while a nighttime earthquake was defined as occurring between 5 p.m. and 12 a.m. The reason why we divided earthquakes as above is that a daytime earthquake was believed to affect the subsequent drinking behavior on the same night. In contrast, a nighttime earthquake that may have occurred while drinking alcohol was believed to have a different effect on drinking behavior. The remaining time period, from 12am to 9am, was considered as having little effect on alcohol behavior.



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137 *Study site*  
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138 St. Luke's International Hospital is located in Chuo-ku, Tokyo, Japan. The hospital, a 520-bed tertiary-  
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139 level community teaching hospital, accepts more than 10,000 ambulance admissions a year. Located close to  
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140 Ginza, a major entertainment district popular for bars and restaurants serving alcohol, St. Luke's receives the  
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141 largest number of ambulances per year, including approximately 50% of ambulances dispatched from the Ginza  
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142 area. We included only earthquakes that were observed in this metropolitan Tokyo area in the analyses.  
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144 *Category of day in relation to work week and seasonality*  
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145 Because the incidence of acute alcohol intoxication is considered to vary substantially by the day of the  
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146 week, we divided the days into three categories: weekdays, days prior to a non-working day, and non-working  
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147 days (generally understood in Japan to be Saturday, Sunday, and designated national holidays). For days  
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148 overlapping categories, we considered days prior to a non-working day the most dominant. For instance,  
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149 because December 31, January 1st, 2nd, and 3rd are designated national holidays in Japan, we categorized  
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150 December 31, January 1st and 2nd as "days prior to a non-working day", and 3rd as a "non-working day".  
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151 As the incidence of acute alcohol intoxication is also considered to be related to seasonality, we  
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152 categorized March, April and May as spring; June, July and August as summer; September, October and  
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153 November as fall; December, January and February as winter.  
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## 155 *Statistical analyses*

156 Because the occurrence of earthquakes on a certain day was considered to be autocorrelated and have  
157 an autoregressive conditional heteroscedasticity (ARCH) effect (Figure), we applied a multivariate generalized  
158 autoregressive conditional heteroscedasticity (GARCH) approach with dynamic conditional correlation to  
159 investigate the association between patient presentation in the ER and acute alcohol intoxication and occurrence  
160 of earthquakes<sup>21-23</sup>. In terms of the primary outcome, we first applied a simple GARCH model with each  
161 variable examining the relationship between hospital admission for acute alcohol intoxication and earthquake  
162 activity, category of day, and seasonality. This was followed by a multivariate GARCH(1,1) model with  
163 variables found to have a *p* value of 0.2 or lower in the simple GARCH model, as well as a year-fixed effect and  
164 changes in alcohol taxation. Alcohol taxation had changed five times during study periods, and it is included the  
165 model as a categorical variable. Because the taxation rates were similar during the study periods (e.g., 45.1%-  
166 46.6% for beer, 16.2%-18.1% for sake), the impact of alcohol taxation change on the results was considered to  
167 be limited. The  $\beta$  coefficient and 95% confidence intervals (CI) were calculated. In addition, we stratified the  
168 analyses by both gender and age (50 years or older versus less than 50 years). Moreover, we separately analyzed  
169 data before the Great East Japan earthquake on March 11, 2011 and after the earthquake. We also conducted  
170 sensitivity analyses to check robustness with the following three methods: using the Richter scale magnitude as  
171 a covariate to evaluate whether the results differ according to the magnitude of the earthquake; introducing  
172 different lag times between the earthquake and hospital visits (e.g., 1, 3 or 7 days after the earthquakes),  
173 excluding days in which severe earthquakes (Shindo scale  $\geq 4$ ) occurred; and having the data stratified by day of  
174 the week. All analyses were performed using Stata 14.0 (Stata Corp, TX, USA).

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## Results

During the study period, earthquakes were observed 706 times with a median Shindo score in the catchment area of 2 (interquartile range 1). During the 4,747 days in the study period, earthquakes were observed on 500 days. During this period, 6,571 patients were extracted from the electronic medical record. Among them, 99 were excluded because they were younger than 20 years old, and 77 were excluded based on the blood alcohol level. Finally, 6,395 patients with a mean age of 42.6 (*SD* 16.9) were treated for acute ethanol intoxication; 4,592 (71.8%) were male (Table 1).

Table 2 shows the results for the number of patients with acute ethanol intoxication from the simple and multivariate GRACH models. In univariate analyses, the daytime earthquake figure was marginally and inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01). The number of days prior to a non-working day ( $\beta$  coefficient: 0.26, 95%CI: 0.15 - 0.37) was significantly related and the number of non-working days ( $\beta$  coefficient: 0.08, 95%CI: -0.01 - 0.14) was marginally significantly related to acute intoxication. These findings remained similar in multivariate analyses after adjusting for both occurrences of a daytime earthquake, category of day, seasonality, year-fixed effect and change in alcohol taxation.

In a sensitivity analysis, including Richter scale magnitude as a covariate to evaluate whether the results differ according to the magnitude of the earthquake, the daytime earthquake number was still marginally related to decreased patient volume ( $\beta$  coefficient: -0.23, 95% CI: -0.47 - 0.01). However, the magnitude of the earthquake itself had no relationship with patient volume ( $\beta$  coefficient: 0.01, 95% CI: -0.02 - 0.04). When we introduced different lag times between the earthquake and hospital visits, the number of daytime earthquakes

was also marginally significantly related to decreased patient volume ( $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.01 for 1 day after an earthquake;  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 3 days after an earthquake; and  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 7 days after an earthquake), while different lag times themselves were not associated with patient volume. When we excluded days in which severe earthquakes (Shindo scale  $\geq 4$ ) occurred, the findings were similar [daytime earthquake ( $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02)]. In the analyses by stratification of day of the week, the number of daytime earthquakes was not related to patient volume on weekdays ( $\beta$  coefficient: 0.01, 95% CI: -0.28 - 0.30) but tend to be negatively related to patient volume on days off ( $\beta$  coefficient: -0.15, 95% CI: -0.49 - 0.19). The analysis was not concaved in the days prior to days off.

Table 3 shows the result of the number of patients with alcohol intoxication from univariate and multivariate analyses stratified by gender. The inverse association between daytime earthquake and alcohol intoxication seen in a pooled analysis was only observed among men ( $p < 0.03$  for males and  $p = 0.99$  for females). Although a positive association between the day before non-working days and acute alcohol intoxication were observed in both males ( $p < 0.01$ ) and females ( $p < 0.01$ ), higher rates of intoxication on non-working days were only observed in women ( $p = 0.02$  for females and  $p = 0.35$  for males). Among male patients, the number of patients with acute alcohol intoxication rose in the winter compared to spring ( $p = 0.01$ ), but not among females ( $p = 0.42$ ).

Table 4 shows the result for the number of patients with alcohol intoxication from univariate and multivariate analyses stratified by age group. Older people were less likely to be admitted to the ER due to acute alcohol intoxication on days when daytime earthquakes occurred ( $p = 0.11$ ), but the same pattern was not seen

among younger people ( $p=0.36$ ). Both older and younger patients with acute alcohol intoxication were more likely to be admitted on days before non-working days as well as on non-working days compared to weekdays. However, in terms of seasonality, older people were significantly more likely to be admitted to the ER with acute alcohol intoxication in the winter ( $p<0.01$ ), but not younger people ( $p=0.83$ )

In terms of stratification by the date of the Great East Japan earthquake, the number of daytime earthquakes was inversely related to the number of acutely intoxicated patients after the Great East Japan earthquake ( $\beta$  coefficient:  $-0.28$ , 95% CI:  $-0.55 - -0.02$ ), while the number of daytime earthquakes was not related to the number before the Great East Japan earthquake ( $\beta$  coefficient:  $-0.02$ , 95% CI:  $-0.32 - 0.29$ ).

## Discussion

Our study found several predictors of the number of intoxicated patients presenting in the ER of a major urban hospital in Japan. Notably, there was an inverse relationship between the number of intoxicated patients and daytime earthquakes observed in older patients and men.

Although previous studies that evaluated drinking behavior after catastrophic earthquakes reported both positive and negative effects, we found that non-catastrophic earthquakes may exert a dampening (i.e., a health-favorable) effect on excess alcohol consumption. This finding was considered to be a type of stress-related growth, which is the theory that people develop from negative events<sup>24</sup>. We speculate that people may avoid risky behaviors, such as going out with companions after work, to indulge in excessive amounts of drinking immediately after an earthquake. When people experience earthquakes, many may suspect additional tectonic activity; multiple earthquakes in a single day are common and were observed on 83 (16.7%) days in our study. As a result, we suspect that many people choose to go home rather than go out, as has been

documented in reports about catastrophic earthquakes<sup>25</sup>. People may avoid social activities, such as after-work gatherings, on days in which even mild but nevertheless frightening natural phenomena have occurred, thereby reducing the opportunities for excessive drinking and other risky social behaviors. Lower blood alcohol levels noted on earthquake days also suggest that even imbibers may limit the amount of alcohol consumed on such days. Similar social behaviors have been observed after the Great East Japan earthquake in 2011, although whether these behavioral changes are conscious or unconscious remains unclear<sup>26</sup>.

We found both age and gender differences in the relationship between daytime earthquakes and acute alcohol intoxication. There were statistically fewer male patients with acute alcohol intoxication on days when a daytime earthquake occurred compared to days without seismic activity. Interestingly, this relationship was not found for female patients. A previous systematic review reported that differing patterns of alcohol use between men and women are driven by both biological and psycho-socio-cultural factors<sup>27</sup>. As a result, men are more likely to seek sensations, including hazardous drinking, than women in ordinary settings<sup>28,29</sup>. However, it is possible that mild earthquakes may affect these psycho-socio-cultural factors more for men than women. Social capital may play an important role in this<sup>30</sup>. Because most Japanese male workers drink with colleagues after work<sup>31</sup>, some may suggest that others not go out to drink after work on days with earthquakes.

In terms of age, fewer older patients with acute alcohol intoxication were observed on days with earthquakes, despite an unchanged number of younger patients presenting with acute alcohol intoxication on these days. A previous survey about alcohol use reported that younger people tended to indulge in more binge drinking and heavy episodic drinking in Japan<sup>32</sup> and other countries<sup>33</sup>. Psychologically disturbing natural

phenomena, however mild, may also exert specific inhibitory psycho-socio-cultural effects on risky behaviors of younger people. Further research is needed to evaluate the potential mechanisms for these differences.

Significantly fewer patients with acute alcohol intoxication were observed on days with daytime earthquakes compared to those on days without daytime earthquakes after the Great East Japan earthquake, while the finding was not observed before the Great East Japan earthquake. This suggests that people still have catastrophic earthquakes in mind and avoid sensation seeking from stress-related growth.

Our study has some limitations. First, not all potential patients with acute alcohol intoxication were transferred to our hospital, resulting in a measure of selection bias. However, because our hospital has the largest number and highest rate of ambulance acceptances in Tokyo, with more than 50% of ambulances dispatched to the local entertainment area were transferred to us, and we assume that this bias is neither large nor differential. In addition, the findings may not be applicable to other countries because ethnicity and cultural diversity could exist<sup>34</sup>. Second, because we were unable to accurately record information about when patients started to consume alcohol, precise knowledge of the temporal relationship between alcohol consumption, intoxication, and earthquakes is difficult to assess. Similarly, because qualitative data concerning patients' physical and emotional perception of seismic activity is not available, further studies are warranted in this area. In addition, an evaluation for acute stress disorder may be useful to explain the gender and age difference of findings. Finally, an earthquake itself may somewhat impact hospital operations. However, the emergency department of hospitals had operated as usual on and after the Great East Japan earthquake. Therefore, the impact is considered to be limited.



**Conclusion**

On days when mild to moderate daytime earthquakes occurred, our hospital had fewer patients with acute alcohol intoxication presenting in the emergency room. This pattern was also seen for men and elderly patients. Even mild natural phenomena may lead to changes in social behavior that result in avoidance of excessive alcohol use.

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	Patients (n=6,395)
Age, year, mean (SD)	42.6 (16.9)
Male, n (%)	4,592 (71.8)
Blood alcohol level, mg/dl, mean (SD)	225.4 (87.2)
Type of day when the patient visited the hospital	
Weekdays, n (%)	3,125 (48.9)
Days prior to day off, n (%)	1,220 (19.1)
Day off, n (%)	2,050 (32.1)
Season in which the patient visited the hospital	
Spring, n (%)	1,562 (24.4)
Summer, n (%)	1,558 (24.4)
Fall, n (%)	1,617 (25.3)
Winter, n (%)	1,658 (25.9)
Occurrence of earthquake when the patient visited the hospital	
Whole day, n (%)	657 (10.3)
Daytime earthquake, n (%)	197 (3.1)
Nighttime earthquake, n (%)	188 (2.94)

Table 1. Patient's characteristics

Variable	Univariate GARCH* model			Multivariate GARCH* model		
	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value
Earthquake factors						
Incidence of earthquake	0.00	(-0.12 — 0.12)	0.95			
Number of earthquakes a day, times	-0.02	(-0.06 — 0.03)	0.46			
The depth of the epicenter, km	0.00	(-0.01 — 0.01)	0.85			
The highest magnitude in a day	0.00	(-0.02 — 0.02)	0.98			
The highest Shindo in a day	0.00	(-0.08 — 0.07)	0.92			
Daytime earthquake <sup>§</sup>	-0.19	(-0.40 — 0.01)	0.06	-0.18	(-0.38 — 0.02)	0.07
Nighttime earthquake <sup>‡</sup>	0.12	(-0.12 — 0.35)	0.34			
Date						
Categories of day						
Weekday		Reference			Reference	
The day before non-working day	<b>0.26</b>	<b>(0.15 — 0.37)</b>	<b>&lt;0.01</b>	<b>0.25</b>	<b>(0.15 — 0.36)</b>	<b>&lt;0.01</b>
Non-working day	0.08	(-0.01 — 0.17)	0.05	0.08	(-0.01 — 0.16)	0.08
Season						
Spring		Reference			Reference	
Summer	0.02	(-0.09 — 0.13)	0.73	0.02	(-0.09 — 0.12)	0.78
Fall	0.05	(-0.06 — 0.17)	0.35	0.03	(-0.76 — 0.14)	0.55
Winter	0.10	(-0.01 — 0.22)	0.07	<b>0.12</b>	<b>(0.02 — 0.23)</b>	<b>0.02</b>

Table 2.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from the univariate and multivariate GARCH model

\*GARCH stands for generalized autoregressive conditional heteroskedasticity. The multivariate GARCH model was adjusted for variables found to have a *p* value of 0.2 or less in a simple GARCH model as well as year-fixed effect and changes in alcohol taxation.; <sup>†</sup>CI represents confidence interval; <sup>§</sup>Daytime earthquake means that an earthquake was observed between 9 a.m. and 5 p.m.; <sup>‡</sup>Nighttime earthquake means that earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the *p* value is less than 0.05.

Male (*n* = 4,646)Female (*n* = 1,826)

Variable	Male ( <i>n</i> = 4,646)				Female ( <i>n</i> = 1,826)			
	Univariate GARCH*		Multivariate GARCH*		Univariate GARCH*		Multivariate GARCH*	
	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value
Earthquake factors								
Incidence of earthquake	0.00 (-0.11 — 0.10)	0.98			-0.01 (-0.07 — 0.05)	0.86		
Number of earthquakes per day, times	-0.01 (-0.05 — 0.02)	0.39			0.00 (-0.02 — 0.02)	0.79		
The depth of the epicenter, km	0.00 (-0.00 — 0.00)	0.98			0.00 (-0.01 — 0.01)	0.78		
The highest magnitude in a day	0.00 (-0.02 — 0.02)	0.98			0.00 (-0.01 — 0.01)	0.98		
The highest Shindo in a day	-0.01 (-0.07 — 0.05)	0.81			0.00 (-0.03 — 0.04)	0.94		
Daytime earthquake <sup>§</sup>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.02</b>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.03</b>	0.00 (-0.09 — 0.10)	0.95	0.00 (-0.10 — 0.10)	0.99
Nighttime earthquake <sup>‡</sup>	0.05 (-0.14 — 0.25)	0.59			0.05 (-0.07 — 0.16)	0.41		
Date								
Categories of day								
Weekday		Reference				Reference		
The day before a non-working day	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>
Non-working day	0.04 (-0.04 — 0.11)	0.34	0.04 (-0.04 — 0.11)	0.35	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>
Season								
Spring		Reference				Reference		



1		-0.00		-0.00		0.02		0.02	
2	Summer	(-0.10 — 0.09)	0.93	(-0.10 — 0.09)	0.93	(-0.03 — 0.07)	0.42	(-0.03 — 0.08)	0.37
3									
4		0.02		0.02		0.02		0.01	
5	Fall	(-0.07 — 0.12)	0.63	(-0.08 — 0.11)	0.74	(-0.04 — 0.07)	0.55	(-0.04 — 0.07)	0.58
6									
7		<b>0.12</b>		<b>0.12</b>		-0.02		-0.02	
8	Winter	<b>(0.02 — 0.21)</b>	<b>0.01</b>	<b>(0.02 — 0.21)</b>	<b>0.01</b>	(-0.07 — 0.03)	0.43	(-0.07 — 0.03)	0.42
9									

Table 3.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from the univariate and multivariate GARCH model by gender

\*GARCH represents generalized autoregressive conditional heteroskedasticity. The multivariate GARCH model was adjusted for variables found to have  $p$  value of 0.2 or less in a simple GARCH model as well as year-fixed effect and changes in alcohol taxation; †CI represents confidence interval; §Daytime earthquake means that earthquake was observed between 9 a.m. and 5 p.m.; ‡Nighttime earthquake means that earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the  $p$  value is less than 0.05.

Variable	50 years or older ( <i>n</i> = 2,202)				Younger than 50 years ( <i>n</i> = 4,270)			
	Univariate GARCH*		Multivariate GARCH*		Univariate GARCH*		Multivariate GARCH*	
	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value
Earthquake factors								
Incidence of earthquake	-0.03 (-0.10 — 0.04)	0.37			0.03 (-0.07 — 0.13)	0.54		
Number of earthquakes per day, times	-0.01 (-0.03 — 0.01)	0.35			0.00 (-0.04 — 0.03)	0.82		
The depth of the epicenter, km	0.00 (-0.00 — 0.00)	0.67			0.00 (-0.01 — 0.01)	0.98		
The highest magnitude in a day	-0.01 (-0.02 — 0.01)	0.39			0.01 (-0.01 — 0.03)	0.54		
The highest Shindo in a day	-0.02 (-0.06 — 0.02)	0.35			0.02 (-0.04 — 0.08)	0.58		
Daytime earthquake <sup>§</sup>	-0.09 (-0.20 — 0.01)	0.09	-0.09 (-0.19 — 0.02)	0.11	-0.07 (-0.23 — 0.10)	0.39	-0.08 (-0.24 — 0.09)	0.36
Nighttime earthquake <sup>‡</sup>	0.03 (-0.09 — 0.15)	0.65			0.09 (-0.09 — 0.28)	0.32		
Date								
Categories of day								
Weekday			Reference				Reference	
The day before the non-working day	<b>0.06</b> (0.01 — 0.12)	<b>0.02</b>	<b>0.06</b> (0.01 — 0.12)	<b>0.03</b>	<b>0.19</b> <b>(0.11 — 0.28)</b>	<b>&lt;0.01</b>	<b>0.19</b> <b>(0.11 — 0.28)</b>	<b>&lt;0.01</b>
Non-working day	-0.04 (-0.08 — 0.01)	0.09	-0.04 (-0.09 — 0.01)	0.08	<b>0.11</b> <b>(0.04 — 0.18)</b>	<b>&lt;0.01</b>	<b>0.11</b> <b>(0.05 — 0.18)</b>	<b>&lt;0.01</b>
Season								
Spring			Reference				Reference	

1		-0.03		-0.03		0.06		0.06	
2	Summer	(-0.09 — 0.02)	0.26	(-0.09 — 0.02)	0.23	(-0.03 — 0.14)	0.20	(-0.03 — 0.15)	0.17
3									
4		0.01		0.01		0.04		0.03	
5	Fall	(-0.05 — 0.07)	0.73	(-0.05 — 0.06)	0.82	(-0.05 — 0.12)	0.40	(-0.05 — 0.12)	0.45
6									
7		<b>0.10</b>		<b>0.10</b>		0.01		0.01	
8	Winter	<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	(-0.08 — 0.10)	0.81	(-0.08 — 0.79)	0.83
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Table 4.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from univariate and multivariate GARCH model by age

\*GARCH stands for generalized autoregressive conditional heteroskedasticity; †CI represents confidence interval; §Daytime earthquake means that the earthquake was observed between 9 a.m. and 5 p.m.; ‡Nighttime earthquake means that the earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the p value is less than 0.05.

1 **Figure legend:**  
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4 Figure 1. Number of earthquakes per day.  
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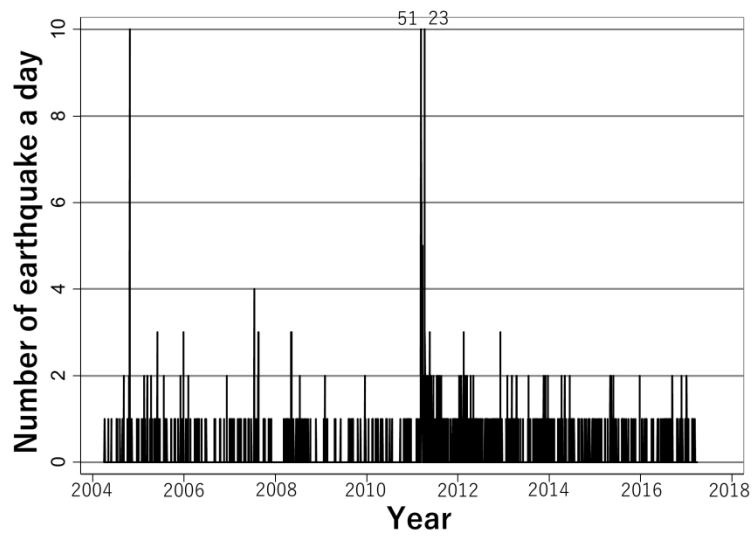


Figure 1. Daily number of earthquake.  
279x215mm (300 x 300 DPI)

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

Check	Page, session		Item No	Recommendation
X	Page1. Title	<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
X	Page2-3, abstract			(b) Provide in the abstract an informative and balanced summary of what was done and what was found
<b>Introduction</b>				
X	Page4-5, introduction	Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
X	Page5, last in Introduction	Objectives	3	State specific objectives, including any prespecified hypotheses
<b>Methods</b>				
X	Page6, first paragraph in Methods	Study design	4	Present key elements of study design early in the paper
X	Page6, first paragraph in Methods	Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
X	Page6, first paragraph in Methods	Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
X	Page6, first and second paragraph in Methods			(b) For matched studies, give matching criteria and number of exposed and unexposed
X	Page7-8, third paragraph in Methods	Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
X	Page7-8, third paragraph in Methods	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
X	Page7-8, third paragraph in Methods	Bias	9	Describe any efforts to address potential sources of bias
X	Page9, third paragraph in statistical analyses	Study size	10	Explain how the study size was arrived at
X	Page8, first and second paragraph in statistical analyses	Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

1	X	Page8, first and second paragraph in statistical analyses	Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
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4	X	Page8, first and second paragraph in statistical analyses			(b) Describe any methods used to examine subgroups and interactions
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8	X	Page8, first and second paragraph in statistical analyses			(c) Explain how missing data were addressed
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10					
11	X	N/A			(d) If applicable, explain how loss to follow-up was addressed
12					
13					
14	X	Page8, first and second paragraph in statistical analyses			(e) Describe any sensitivity analyses
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17					
18			<b>Results</b>		
19	X	Page10, result session	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
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25	X	Page10, result session			(b) Give reasons for non-participation at each stage
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27	X	N/A			(c) Consider use of a flow diagram
28					
29	X	Page10, result session	Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
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33	X	Page10, result session			(b) Indicate number of participants with missing data for each variable of interest
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35	X	Page10, result session			(c) Summarise follow-up time (eg, average and total amount)
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37					
38	X	Page10, result session, table1	Outcome data	15*	Report numbers of outcome events or summary measures over time
39					
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41	X	Page10-11, result session	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
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47	X	Page10-11, result session			(b) Report category boundaries when continuous variables were categorized
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49	X	Page10-11, result session			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
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53	X	Page10-11, result session, Table2.	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
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57			<b>Discussion</b>		
58	X	Page12, first	Key results	18	Summarise key results with reference to
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	paragraph in discussion			study objectives
X	Page 12-14 in discussion	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
X	Page 14	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
X	Page 14	Generalisability	21	Discuss the generalisability (external validity) of the study results
<b>Other information</b>				
X	Page 1	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

\*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>.



# BMJ Open

## Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes: Time series study

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# Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes: Time series study

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Key words: earthquake, alcohol, behavior, alcohol intoxication

**Short title:** alcohol intoxication study

Word count: 3,010 words

**Authors contribution:** DK organized and conducted this study and wrote the whole manuscript. HH, HK, KN, YT, YO and OT contributed to writing the manuscript and made important comments on it. GD and IK contributed to the study design, statistical analyses and discussion.

## Abstract

**Objectives:** Earthquakes are a distressing natural phenomenon that can disrupt normal health-related behaviors. The aim of this study was to investigate changes in alcohol consumption behaviors in the immediate aftermath of mild to moderate earthquakes.

**Setting:** This retrospective cohort study was conducted at a large academic hospital in Tokyo, Japan from April 2004 to March 2017.

**Participants:** We included all adult patients presenting with acute alcohol intoxication in the emergency room.

**Primary and secondary outcome measures:** Our outcome was the number of such patients per 24 hour period comparing days with and without earthquake activity. We mainly focused on mild to moderate earthquakes (Shindo scale of less than 3). We conducted a simple generalized autoregressive conditional heteroscedasticity (GARCH) analysis, followed by a multivariate GARCH, including year-fixed effects and secular changes in alcohol taxation. Subanalyses were conducted by gender and age group.

**Results:** During the study period, 706 earthquakes were observed with a median Shindo scale of 2 (IQR: 1). During this period, 6,395 patients were admitted with acute ethanol intoxication; the mean age was 42.6 (SD: 16.9) years, and 4,592 (71.8%) patients were male. In univariate analyses, the occurrence of daytime earthquakes was marginally inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01). This finding remained similar in multivariate analyses after adjustment for covariates. In analyses stratified by gender, the inverse association between daytime earthquakes and alcohol intoxication was only observed among men ( $p < 0.03$  for males and  $p = 0.99$  for females). In subanalyses by

age, older people were less likely to be admitted to the hospital due to acute alcohol intoxication on days with daytime earthquakes ( $p=0.11$ ), but this was not the case for younger people ( $p=0.36$ ).

**Conclusion:** On days when a mild to moderate daytime earthquake occurred, the number of patients with acute alcohol intoxication was lower compared to days without earthquakes. Even milder forms of potentially catastrophic events appear to influence social behavior; mild to moderate earthquake activity is associated with the avoidance of excessive alcohol consumption.

### *Article summary*

#### Strengths and limitations of this study

- This unique study is the first to evaluate alcohol consumption behavior in the immediate aftermath of earthquakes.
- Robust analyses supported the findings in this study.
- The limitation of this study was its analysis of a single center with a single ethnicity.

## Introduction

Catastrophic earthquake activity has been reported to exert a variety of effects on both physical and mental health<sup>1</sup>. A previous study reported that approximately 42.6% of victims exhibited moderate to serious mental health problems after the Great East Japan earthquake, which occurred in March 2011<sup>1</sup>. Acute health effects associated with earthquake activity include acute stress disorders<sup>2</sup>, delirium,<sup>3</sup> and acute and transient psychotic disorders. Longer-term effects on victims' well-being have also been reported, including post-traumatic stress disorder and exacerbation of bipolar disorder<sup>4-6</sup>. Although most previous research has been limited to the health impacts of rare catastrophic earthquakes, very few studies have focused on the health effects associated with substantially more common mild to moderate earthquakes.

Substance abuse is a common disorder reported in the setting of catastrophic disasters<sup>7,8</sup>. Several studies have explored this relationship with regard to alcohol use behaviors<sup>9,10</sup>, with several previous studies reporting an increased prevalence of alcohol abuse after major earthquakes.<sup>11,12</sup> However, in the larger context of catastrophic phenomena, this association remains unclear, with one report showing only a 2% increase in prevalence after a major hurricane<sup>13</sup> and other studies reporting a slight decrease in alcohol abuse after instances of terrorism<sup>9,14</sup>. Moreover, some suggested that disasters have rarely increased the prevalence of substance use disorders. Instead, increased alcohol abuse after disaster can often reflect an exacerbation of existing abuse rather than new onset disorders<sup>15</sup>. As such, the effect of disasters on alcohol abuse remains controversial. Previous studies have suggested that gender, age, education, and even cultural background modify these associations.<sup>16,17</sup>

Japan is a tectonically active country where earthquakes are observed frequently. The Japan Meteorological Agency observed 2,025 earthquakes in 2017, and more than 6,500 earthquakes were

95 observed in 2016 in Japan <sup>18</sup>. Among the 76 earthquakes in 2017 and 123 events in 2016, 3.8% and 1.9%,  
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96 respectively, were greater than a magnitude of 5. In addition to the incidence of earthquakes, the Japan  
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97 Meteorological Agency recorded the date, time, magnitude, location, and seismic intensity <sup>19</sup>. Thus, the aim  
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98 of this study was to evaluate the same-day association between mild to moderate earthquakes and unhealthy  
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99 alcohol use behavior in Japan.  
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## 100 *Methods*

### 101 *Study design and cohort description*

102 We conducted a retrospective daily time series study using medical record data from St. Luke's  
103 International Hospital in Tokyo, Japan from April 2004 to March 2017.

### 104 *Patient and Public Involvement*

105 We included all patients who were 20 or older and presented to the hospital emergency room with  
106 acute alcohol intoxication. We excluded all patients who signed opt-out agreements for their anonymized  
107 data to be used in research. In addition, patients presenting with an altered mental status of uncertain origin  
108 were excluded. Our outcome was a patient volume of acutely intoxicated patients per 24-hour period.  
109 Outcomes were compared between days with and without earthquakes, as observed by the Japan  
110 Meteorological Agency. The ethical committee at St. Luke's International Hospital approved this study  
111 (approval number: 17-R025).

### 112 *Research ethics application*

113 In terms of data sharing, no additional patient data were available, although data about earthquakes  
114 were available on the Japan Meteorological Agency website<sup>18</sup>. This study was entirely the authors' own  
115 work, and no funding supported this study. The results of this study will be disseminated through  
116 publication, and individual participants will not be alerted because this was a retrospective design.

### 117 *Acute alcohol intoxication*

118 Emergency physicians at the hospital clinically diagnosed acute alcohol intoxication based on  
119 testimonies by patients or their companions. A blood ethanol level of 100 mg/dl or higher was used to  
120 support the diagnosis for those whose testimonies could not be elicited directly<sup>20</sup>.

## Earthquake

All earthquake data were obtained from the Japan Meteorological Agency<sup>18</sup>. The recorded data contain the time and date of occurrence, the Richter magnitude, the depth of epicenter, and Shindo scale data for any earthquake detected. With a range of 0 to 7, Shindo is the unique measurement scale used in Japan for seismic intensities in a specific area<sup>19</sup>. Unlike the Richter scale, which represents the size of the earthquake itself and is unique for each earthquake, Shindo scaling reflects the intensity of the observed shaking in a given area and is based on the distance from the epicenter at which the seismic activity was observed. Generally speaking, the further the observed area is from the epicenter, the lower the Shindo measurement is for that area. A Shindo score of 1 is comparable to mild shaking observed only when sitting quietly in a structure, while a Shindo score of 4 is defined as observable shaking that is intense enough to startle, awaken people from sleep, and can be detected while walking. A Shindo score of 7 equates to severe shaking in which it is impossible to remain standing or move without crawling. In terms of the severity of the earthquake, we defined earthquakes with a Shindo score of 1 – 3 as mild to moderate earthquakes and those with a Shindo score of 4 or more as severe earthquakes. We defined a daytime earthquake as one observed between 9 a.m. and 5 p.m., while a nighttime earthquake was defined as occurring between 5 p.m. and 12 a.m. The reason why we divided earthquakes as above is that a daytime earthquake was believed to affect the subsequent drinking behavior on the same night. In contrast, a nighttime earthquake that may have occurred while drinking alcohol was believed to have a different effect on drinking behavior. The remaining time period, from 12am to 9am, was considered as having little effect on alcohol behavior.



142 *Study site*

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5 St. Luke's International Hospital is located in Chuo-ku, Tokyo, Japan. The hospital, a 520-bed  
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8 tertiary-level community teaching hospital, accepts more than 10,000 ambulance admissions a year. Located  
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11 close to Ginza, a major entertainment district popular for bars and restaurants serving alcohol, St. Luke's  
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14 receives the largest number of ambulances per year, including approximately 50% of ambulances dispatched  
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17 from the Ginza area. We included only earthquakes that were observed in this metropolitan Tokyo area in  
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20 the analyses.

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*Category of day in relation to work week and seasonality*

Because the incidence of acute alcohol intoxication is considered to vary substantially by the day of  
the week, we divided the days into three categories: weekdays, days prior to a non-working day, and non-  
working days (generally understood in Japan to be Saturday, Sunday, and designated national holidays). For  
days overlapping categories, we considered days prior to a non-working day the most dominant. For  
instance, because December 31, January 1st, 2nd, and 3rd are designated national holidays in Japan, we  
categorized December 31, January 1st and 2nd as "days prior to a non-working day", and 3rd as a "non-  
working day".

As the incidence of acute alcohol intoxication is also considered to be related to seasonality, we  
categorized March, April and May as spring; June, July and August as summer; September, October and  
November as fall; December, January and February as winter.

162 *Statistical analyses*

163 Because the occurrence of earthquakes on a certain day was considered to be autocorrelated and  
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164 have an autoregressive conditional heteroscedasticity (ARCH) effect (Figure), we applied a multivariate  
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165 generalized autoregressive conditional heteroscedasticity (GARCH) approach with dynamic conditional  
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166 correlation to investigate the association between patient presentation in the ER and acute alcohol  
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167 intoxication and occurrence of earthquakes <sup>21-23</sup>. In terms of the primary outcome, we first applied a simple  
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168 GARCH model with each variable examining the relationship between hospital admission for acute alcohol  
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169 intoxication and earthquake activity, category of day, and seasonality. This was followed by a multivariate  
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170 GARCH(1,1) model with variables found to have a *p* value of 0.2 or lower in the simple GARCH model, as  
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171 well as a year-fixed effect and changes in alcohol taxation. Alcohol taxation had changed five times during  
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172 study periods, and it is included the model as a categorical variable. Because the taxation rates were similar  
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173 during the study periods (e.g., 45.1%- 46.6% for beer, 16.2%-18.1% for sake), the impact of alcohol taxation  
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174 change on the results was considered to be limited. The  $\beta$  coefficient and 95% confidence intervals (CI)  
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175 were calculated. In addition, we stratified the analyses by both gender and age (50 years or older versus less  
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176 than 50 years). Moreover, we separately analyzed data before the Great East Japan earthquake on March 11,  
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177 2011 and after the earthquake. We also conducted sensitivity analyses to check robustness with the  
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178 following three methods: using the Richter scale magnitude as a covariate to evaluate whether the results  
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179 differ according to the magnitude of the earthquake; introducing different lag times between the earthquake  
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180 and hospital visits (e.g., 1, 3 or 7 days after the earthquakes), excluding days in which severe earthquakes  
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181 (Shindo scale  $\geq 4$ ) occurred; and having the data stratified by day of the week. All analyses were performed  
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182 using Stata 14.0 (Stata Corp, TX, USA).  
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## Results

During the study period, earthquakes were observed 706 times with a median Shindo score in the catchment area of 2 (interquartile range 1). During the 4,747 days in the study period, earthquakes were observed on 500 days. During this period, 6,571 patients were extracted from the electronic medical record. Among them, 99 were excluded because they were younger than 20 years old, and 77 were excluded based on the blood alcohol level. Finally, 6,395 patients with a mean age of 42.6 (*SD* 16.9) were treated for acute ethanol intoxication; 4,592 (71.8%) were male (Table 1).

Table 2 shows the results for the number of patients with acute ethanol intoxication from the simple and multivariate GRACH models. In univariate analyses, the daytime earthquake figure was marginally and inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01). The number of days prior to a non-working day ( $\beta$  coefficient: 0.26, 95%CI: 0.15 - 0.37) was significantly related and the number of non-working days ( $\beta$  coefficient: 0.08, 95%CI: -0.01 - 0.14) was marginally significantly related to acute intoxication. These findings remained similar in multivariate analyses after adjusting for both occurrences of a daytime earthquake, category of day, seasonality, year-fixed effect and change in alcohol taxation.

In a sensitivity analysis, including Richter scale magnitude as a covariate to evaluate whether the results differ according to the magnitude of the earthquake, the daytime earthquake number was still marginally related to decreased patient volume ( $\beta$  coefficient: -0.23, 95% CI: -0.47 - 0.01). However, the magnitude of the earthquake itself had no relationship with patient volume ( $\beta$  coefficient: 0.01, 95% CI: -0.02 - 0.04). When we introduced different lag times between the earthquake and hospital visits, the number of daytime earthquakes was also marginally significantly related to decreased patient volume ( $\beta$  coefficient:

-0.18, 95% CI: -0.38 - 0.01 for 1 day after an earthquake;  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 3 days after an earthquake; and  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 7 days after an earthquake), while different lag times themselves were not associated with patient volume. When we excluded days in which severe earthquakes (Shindo scale  $\geq 4$ ) occurred, the findings were similar [daytime earthquake ( $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02)]. In the analyses by stratification of day of the week, the number of daytime earthquakes was not related to patient volume on weekdays ( $\beta$  coefficient: 0.01, 95% CI: -0.28 - 0.30) but tend to be negatively related to patient volume on days off ( $\beta$  coefficient: -0.15, 95% CI: -0.49 - 0.19). The analysis was not concaved in the days prior to days off.

Table 3 shows the result of the number of patients with alcohol intoxication from univariate and multivariate analyses stratified by gender. The inverse association between daytime earthquake and alcohol intoxication seen in a pooled analysis was only observed among men ( $p < 0.03$  for males and  $p = 0.99$  for females). Although a positive association between the day before non-working days and acute alcohol intoxication were observed in both males ( $p < 0.01$ ) and females ( $p < 0.01$ ), higher rates of intoxication on non-working days were only observed in women ( $p = 0.02$  for females and  $p = 0.35$  for males). Among male patients, the number of patients with acute alcohol intoxication rose in the winter compared to spring ( $p = 0.01$ ), but not among females ( $p = 0.42$ ).

Table 4 shows the result for the number of patients with alcohol intoxication from univariate and multivariate analyses stratified by age group. Older people were less likely to be admitted to the ER due to acute alcohol intoxication on days when daytime earthquakes occurred ( $p = 0.11$ ), but the same pattern was not seen among younger people ( $p = 0.36$ ). Both older and younger patients with acute alcohol intoxication were more likely to be admitted on days before non-working days as well as on non-working days compared

to weekdays. However, in terms of seasonality, older people were significantly more likely to be admitted to the ER with acute alcohol intoxication in the winter ( $p<0.01$ ), but not younger people ( $p=0.83$ )

In terms of stratification by the date of the Great East Japan earthquake, the number of daytime earthquakes was inversely related to the number of acutely intoxicated patients after the Great East Japan earthquake ( $\beta$  coefficient: -0.28, 95% CI: -0.55 - -0.02), while the number of daytime earthquakes was not related to the number before the Great East Japan earthquake ( $\beta$  coefficient: -0.02, 95% CI: -0.32 - 0.29).

### **Discussion**

Our study found several predictors of the number of intoxicated patients presenting in the ER of a major urban hospital in Japan. Notably, there was an inverse relationship between the number of intoxicated patients and daytime earthquakes observed in older patients and men.

Although previous studies that evaluated drinking behavior after catastrophic earthquakes reported both positive and negative effects, we found that non-catastrophic earthquakes may exert a dampening (i.e., a health-favorable) effect on excess alcohol consumption. This finding was considered to be a type of stress-related growth, which is the theory that people develop from negative events<sup>24</sup>. We speculate that people may avoid risky behaviors, such as going out with companions after work, to indulge in excessive amounts of drinking immediately after an earthquake. When people experience earthquakes, many may suspect additional tectonic activity; multiple earthquakes in a single day are common and were observed on 83 (16.7%) days in our study. As a result, we suspect that many people choose to go home rather than go out, as has been documented in reports about catastrophic earthquakes<sup>25</sup>. People may avoid social activities, such as after-work gatherings, on days in which even mild but nevertheless frightening natural phenomena have occurred, thereby reducing the opportunities for excessive drinking and other risky social behaviors. Lower

247 blood alcohol levels noted on earthquake days also suggest that even imbibers may limit the amount of  
248 alcohol consumed on such days. Similar social behaviors have been observed after the Great East Japan  
249 earthquake in 2011, although whether these behavioral changes are conscious or unconscious remains  
250 unclear <sup>26</sup>.

251 We found both age and gender differences in the relationship between daytime earthquakes and  
252 acute alcohol intoxication. There were statistically fewer male patients with acute alcohol intoxication on  
253 days when a daytime earthquake occurred compared to days without seismic activity. Interestingly, this  
254 relationship was not found for female patients. A previous systematic review reported that differing patterns  
255 of alcohol use between men and women are driven by both biological and psycho-socio-cultural factors <sup>27</sup>.  
256 As a result, men are more likely to seek sensations, including hazardous drinking, than women in ordinary  
257 settings <sup>28,29</sup>. However, it is possible that mild earthquakes may affect these psycho-socio-cultural factors  
258 more for men than women. Social capital may play an important role in this <sup>30</sup>. Because most Japanese male  
259 workers drink with colleagues after work <sup>31</sup>, some may suggest that others not go out to drink after work on  
260 days with earthquakes.

261 In terms of age, fewer older patients with acute alcohol intoxication were observed on days with  
262 earthquakes, despite an unchanged number of younger patients presenting with acute alcohol intoxication on  
263 these days. A previous survey about alcohol use reported that younger people tended to indulge in more  
264 binge drinking and heavy episodic drinking in Japan <sup>32</sup> and other countries <sup>33</sup>. Psychologically disturbing  
265 natural phenomena, however mild, may also exert specific inhibitory psycho-socio-cultural effects on risky  
266 behaviors of younger people. Further research is needed to evaluate the potential mechanisms for these  
267 differences.

268 Significantly fewer patients with acute alcohol intoxication were observed on days with daytime  
269 earthquakes compared to those on days without daytime earthquakes after the Great East Japan earthquake,  
270 while the finding was not observed before the Great East Japan earthquake. This suggests that people still  
271 have catastrophic earthquakes in mind and avoid sensation seeking from stress-related growth.

272 Our study has some limitations. First, not all potential patients with acute alcohol intoxication  
273 were transferred to our hospital, resulting in a measure of selection bias. However, because our hospital has  
274 the largest number and highest rate of ambulance acceptances in Tokyo, with more than 50% of ambulances  
275 dispatched to the local entertainment area were transferred to us, and we assume that this bias is neither  
276 large nor differential. In addition, the findings may not be applicable to other countries because ethnicity and  
277 cultural diversity could exist<sup>34</sup>. Second, because we were unable to accurately record information about  
278 when patients started to consume alcohol, precise knowledge of the temporal relationship between alcohol  
279 consumption, intoxication, and earthquakes is difficult to assess. Similarly, because qualitative data  
280 concerning patients' physical and emotional perception of seismic activity is not available, further studies  
281 are warranted in this area. In addition, an evaluation for acute stress disorder may be useful to explain the  
282 gender and age difference of findings. Finally, an earthquake itself may somewhat impact hospital  
283 operations. However, the emergency department of hospitals had operated as usual on and after the Great  
284 East Japan earthquake. Therefore, the impact is considered to be limited.

**Conclusion**

On days when mild to moderate daytime earthquakes occurred, our hospital had fewer patients with acute alcohol intoxication presenting in the emergency room. This pattern was also seen for men and elderly patients. Even mild natural phenomena may lead to changes in social behavior that result in avoidance of excessive alcohol use.

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	Patients (n=6,395)
Age, year, mean (SD)	42.6 (16.9)
Male, n (%)	4,592 (71.8)
Blood alcohol level, mg/dl, mean (SD)	225.4 (87.2)
Type of day when the patient visited the hospital	
Weekdays, n (%)	3,125 (48.9)
Days prior to day off, n (%)	1,220 (19.1)
Day off, n (%)	2,050 (32.1)
Season in which the patient visited the hospital	
Spring, n (%)	1,562 (24.4)
Summer, n (%)	1,558 (24.4)
Fall, n (%)	1,617 (25.3)
Winter, n (%)	1,658 (25.9)
Occurrence of earthquake when the patient visited the hospital	
Whole day, n (%)	657 (10.3)
Daytime earthquake, n (%)	197 (3.1)
Nighttime earthquake, n (%)	188 (2.94)

Table 1. Patient's characteristics

Variable	Univariate GARCH* model			Multivariate GARCH* model		
	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value
Earthquake factors						
Incidence of earthquake	0.00	(-0.12 — 0.12)	0.95			
Number of earthquakes a day, times	-0.02	(-0.06 — 0.03)	0.46			
The depth of the epicenter, km	0.00	(-0.01 — 0.01)	0.85			
The highest magnitude in a day	0.00	(-0.02 — 0.02)	0.98			
The highest Shindo in a day	0.00	(-0.08 — 0.07)	0.92			
Daytime earthquake <sup>§</sup>	-0.19	(-0.40 — 0.01)	0.06	-0.18	(-0.38 — 0.02)	0.07
Nighttime earthquake <sup>‡</sup>	0.12	(-0.12 — 0.35)	0.34			
Date						
Categories of day						
Weekday		Reference			Reference	
The day before non-working day	<b>0.26</b>	<b>(0.15 — 0.37)</b>	<b>&lt;0.01</b>	<b>0.25</b>	<b>(0.15 — 0.36)</b>	<b>&lt;0.01</b>
Non-working day	0.08	(-0.01 — 0.17)	0.05	0.08	(-0.01 — 0.16)	0.08
Season						
Spring		Reference			Reference	
Summer	0.02	(-0.09 — 0.13)	0.73	0.02	(-0.09 — 0.12)	0.78
Fall	0.05	(-0.06 — 0.17)	0.35	0.03	(-0.76 — 0.14)	0.55
Winter	0.10	(-0.01 — 0.22)	0.07	<b>0.12</b>	<b>(0.02 — 0.23)</b>	<b>0.02</b>

Table 2.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from the univariate and multivariate GARCH model

\*GARCH stands for generalized autoregressive conditional heteroskedasticity. The multivariate GARCH model was adjusted for variables found to have a *p* value of 0.2 or less in a simple GARCH model as well as year-fixed effect and changes in alcohol taxation.; <sup>†</sup>CI represents confidence interval; <sup>§</sup>Daytime earthquake means that an earthquake was observed between 9 a.m. and 5 p.m.; <sup>‡</sup>Nighttime earthquake means that earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the *p* value is less than 0.05.

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Variable	Male ( <i>n</i> = 4,646)				Female ( <i>n</i> = 1,826)			
	Univariate GARCH*		Multivariate GARCH*		Univariate GARCH*		Multivariate GARCH*	
	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value
Earthquake factors								
Incidence of earthquake	0.00 (-0.11 — 0.10)	0.98			-0.01 (-0.07 — 0.05)	0.86		
Number of earthquakes per day, times	-0.01 (-0.05 — 0.02)	0.39			0.00 (-0.02 — 0.02)	0.79		
The depth of the epicenter, km	0.00 (-0.00 — 0.00)	0.98			0.00 (-0.01 — 0.01)	0.78		
The highest magnitude in a day	0.00 (-0.02 — 0.02)	0.98			0.00 (-0.01 — 0.01)	0.98		
The highest Shindo in a day	-0.01 (-0.07 — 0.05)	0.81			0.00 (-0.03 — 0.04)	0.94		
Daytime earthquake <sup>§</sup>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.02</b>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.03</b>	0.00 (-0.09 — 0.10)	0.95	0.00 (-0.10 — 0.10)	0.99
Nighttime earthquake <sup>‡</sup>	0.05 (-0.14 — 0.25)	0.59			0.05 (-0.07 — 0.16)	0.41		
Date								
Categories of day								
Weekday		Reference				Reference		
The day before a non-working day	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>
Non-working day	0.04 (-0.04 — 0.11)	0.34	0.04 (-0.04 — 0.11)	0.35	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>
Season								



		Reference		Reference		Reference		Reference
1	Spring							
2		-0.00		-0.00		0.02		0.02
3		(-0.10 — 0.09)	0.93	(-0.10 — 0.09)	0.93	(-0.03 — 0.07)	0.42	(-0.03 — 0.08) 0.37
4	Summer							
5		0.02		0.02		0.02		0.01
6		(-0.07 — 0.12)	0.63	(-0.08 — 0.11)	0.74	(-0.04 — 0.07)	0.55	(-0.04 — 0.07) 0.58
7	Fall							
8		<b>0.12</b>		<b>0.12</b>		-0.02		-0.02
9		<b>(0.02 — 0.21)</b>	<b>0.01</b>	<b>(0.02 — 0.21)</b>	<b>0.01</b>	(-0.07 — 0.03)	0.43	(-0.07 — 0.03) 0.42
10	Winter							

Table 3.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from the univariate and multivariate GARCH model by gender

\*GARCH represents generalized autoregressive conditional heteroskedasticity. The multivariate GARCH model was adjusted for variables found to have  $p$  value of 0.2 or less in a simple GARCH model as well as year-fixed effect and changes in alcohol taxation; †CI represents confidence interval; §Daytime earthquake means that earthquake was observed between 9 a.m. and 5 p.m.; ‡Nighttime earthquake means that earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the  $p$  value is less than 0.05.

50 years or older ( $n = 2,202$ )Younger than 50 years ( $n = 4,270$ )

Univariate GARCH\*

Multivariate GARCH\*

Univariate GARCH\*

Multivariate GARCH\*

 $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value

Variable

## Earthquake factors

	-0.03	0.37			0.03	0.54		
Incidence of earthquake	(-0.10 — 0.04)				(-0.07 — 0.13)			
	-0.01	0.35			0.00	0.82		
Number of earthquakes per day, times	(-0.03 — 0.01)				(-0.04 — 0.03)			
	0.00	0.67			0.00	0.98		
The depth of the epicenter, km	(-0.00 — 0.00)				(-0.01 — 0.01)			
	-0.01	0.39			0.01	0.54		
The highest magnitude in a day	(-0.02 — 0.01)				(-0.01 — 0.03)			
	-0.02	0.35			0.02	0.58		
The highest Shindo in a day	(-0.06 — 0.02)				(-0.04 — 0.08)			
	-0.09	0.09	-0.09	0.11	-0.07	0.39	-0.08	0.36
Daytime earthquake <sup>§</sup>	(-0.20 — 0.01)		(-0.19 — 0.02)		(-0.23 — 0.10)		(-0.24 — 0.09)	
	0.03	0.65			0.09	0.32		
Nighttime earthquake <sup>‡</sup>	(-0.09 — 0.15)				(-0.09 — 0.28)			

## Date

## Categories of day

Weekday		Reference				Reference		
	<b>0.06</b>	<b>0.02</b>	<b>0.06</b>	<b>0.03</b>	<b>0.19</b>	<b>&lt;0.01</b>	<b>0.19</b>	<b>&lt;0.01</b>
The day before the non-working day	(0.01 — 0.12)		(0.01 — 0.12)		( <b>0.11 — 0.28</b> )		( <b>0.11 — 0.28</b> )	
	-0.04	0.09	-0.04	0.08	<b>0.11</b>	<b>&lt;0.01</b>	<b>0.11</b>	<b>&lt;0.01</b>
Non-working day	(-0.08 — 0.01)		(-0.09 — 0.01)		( <b>0.04 — 0.18</b> )		( <b>0.05 — 0.18</b> )	

## Season

		Reference		Reference		Reference		Reference
1	Spring							
2		-0.03		-0.03		0.06		0.06
3		(-0.09 — 0.02)	0.26	(-0.09 — 0.02)	0.23	(-0.03 — 0.14)	0.20	(-0.03 — 0.15)
4	Summer							0.17
5		0.01		0.01		0.04		0.03
6		(-0.05 — 0.07)	0.73	(-0.05 — 0.06)	0.82	(-0.05 — 0.12)	0.40	(-0.05 — 0.12)
7	Fall							0.45
8		<b>0.10</b>		<b>0.10</b>		0.01		0.01
9		<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	(-0.08 — 0.10)	0.81	(-0.08 — 0.79)
10	Winter							0.83

Table 4.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from univariate and multivariate GARCH model by age

\*GARCH stands for generalized autoregressive conditional heteroskedasticity; †CI represents confidence interval; §Daytime earthquake means that the earthquake was observed between 9 a.m. and 5 p.m.; ‡Nighttime earthquake means that the earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the p value is less than 0.05.

1 **Figure legend:**

2  
3  
4 Figure 1. Number of earthquakes per day.  
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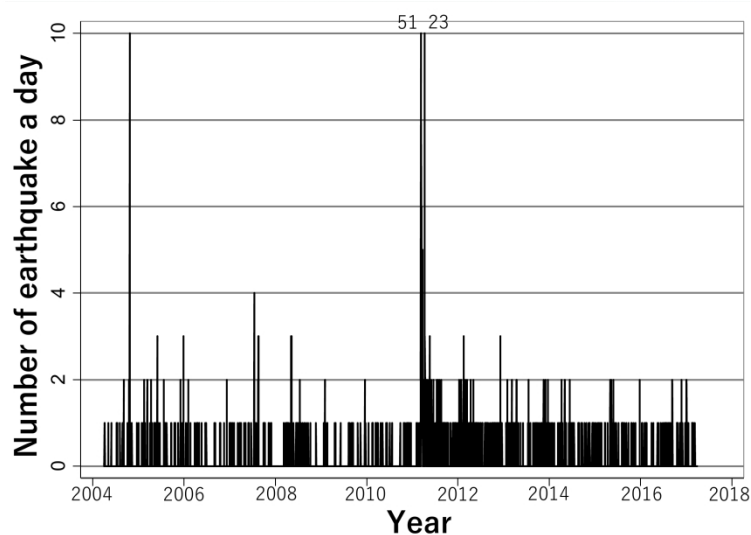


Figure 1. Daily number of earthquake.

279x215mm (300 x 300 DPI)

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

Check	Page, session		Item No	Recommendation
X	Page1. Title	<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
X	Page2-3, abstract			(b) Provide in the abstract an informative and balanced summary of what was done and what was found
<b>Introduction</b>				
X	Page4-5, introduction	Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
X	Page5, last in Introduction	Objectives	3	State specific objectives, including any prespecified hypotheses
<b>Methods</b>				
X	Page6, first paragraph in Methods	Study design	4	Present key elements of study design early in the paper
X	Page6, first paragraph in Methods	Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
X	Page6, first paragraph in Methods	Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
X	Page6, first and second paragraph in Methods			(b) For matched studies, give matching criteria and number of exposed and unexposed
X	Page7-8, third paragraph in Methods	Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
X	Page7-8, third paragraph in Methods	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
X	Page7-8, third paragraph in Methods	Bias	9	Describe any efforts to address potential sources of bias
X	Page9, third paragraph in statistical analyses	Study size	10	Explain how the study size was arrived at
X	Page8, first and second paragraph in statistical analyses	Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

1	X	Page8, first and second paragraph in statistical analyses	Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
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4	X	Page8, first and second paragraph in statistical analyses			(b) Describe any methods used to examine subgroups and interactions
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8	X	Page8, first and second paragraph in statistical analyses			(c) Explain how missing data were addressed
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11	X	N/A			(d) If applicable, explain how loss to follow-up was addressed
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14	X	Page8, first and second paragraph in statistical analyses			(e) Describe any sensitivity analyses
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18			<b>Results</b>		
19	X	Page10, result session	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
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25	X	Page10, result session			(b) Give reasons for non-participation at each stage
26					
27	X	N/A			(c) Consider use of a flow diagram
28					
29	X	Page10, result session	Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
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33	X	Page10, result session			(b) Indicate number of participants with missing data for each variable of interest
34					
35	X	Page10, result session			(c) Summarise follow-up time (eg, average and total amount)
36					
37					
38	X	Page10, result session, table1	Outcome data	15*	Report numbers of outcome events or summary measures over time
39					
40	X	Page10-11, result session	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
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47	X	Page10-11, result session			(b) Report category boundaries when continuous variables were categorized
48					
49	X	Page10-11, result session			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
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53	X	Page10-11, result session, Table2.	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
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57			<b>Discussion</b>		
58	X	Page12, first	Key results	18	Summarise key results with reference to
59					
60					

1				study objectives
2		paragraph in discussion		
3	X	Page 12-14 in discussion	Limitations	19
4				Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
5				
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8	X	Page 14	Interpretation	20
9				Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
10				
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14	X	Page 14	Generalisability	21
15				Discuss the generalisability (external validity) of the study results
16				
17			<b>Other information</b>	
18	X	Page 1	Funding	22
19				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
20				
21				
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\*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>.



# BMJ Open

## Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes: Time series study

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# Alcohol Consumption Behaviors in the Immediate Aftermath of Earthquakes: Time series study

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**Short title:** alcohol intoxication study

Word count: 3,010 words

**Authors contribution:** DK organized and conducted this study and wrote the whole manuscript. HH, HK, KN, YT, YO and OT contributed to writing the manuscript and made important comments on it. GD and IK contributed to the study design, statistical analyses and discussion.

## Abstract

**Objectives:** Earthquakes are a distressing natural phenomenon that can disrupt normal health-related behaviors. The aim of this study was to investigate changes in alcohol consumption behaviors in the immediate aftermath of mild to moderate earthquakes.

**Setting:** This retrospective cohort study was conducted at a large academic hospital in Tokyo, Japan from April 2004 to March 2017.

**Participants:** We included all adult patients presenting with acute alcohol intoxication in the emergency room.

**Primary and secondary outcome measures:** Our outcome was the number of such patients per 24 hour period comparing days with and without earthquake activity. We mainly focused on mild to moderate earthquakes (Shindo scale of less than 3). We conducted a simple generalized autoregressive conditional heteroscedasticity (GARCH) analysis, followed by a multivariate GARCH, including year-fixed effects and secular changes in alcohol taxation. Subanalyses were conducted by gender and age group.

**Results:** During the study period, 706 earthquakes were observed with a median Shindo scale of 2 (IQR: 1). During this period, 6,395 patients were admitted with acute ethanol intoxication; the mean age was 42.6 (SD: 16.9) years, and 4,592 (71.8%) patients were male. In univariate analyses, the occurrence of daytime earthquakes was marginally inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01). This finding remained similar in multivariate analyses after adjustment for covariates. In analyses stratified by gender, the inverse association between daytime earthquakes and alcohol intoxication was only observed among men ( $p < 0.03$  for males and  $p = 0.99$  for females). In subanalyses by

age, older people were less likely to be admitted to the hospital due to acute alcohol intoxication on days with daytime earthquakes ( $p=0.11$ ), but this was not the case for younger people ( $p=0.36$ ).

**Conclusion:** On days when a mild to moderate daytime earthquake occurred, the number of patients with acute alcohol intoxication was lower compared to days without earthquakes. Even milder forms of potentially catastrophic events appear to influence social behavior; mild to moderate earthquake activity is associated with the avoidance of excessive alcohol consumption.

### *Article summary*

#### Strengths and limitations of this study

- This unique study is the first to evaluate alcohol consumption behavior in the immediate aftermath of earthquakes.
- Robust analyses, by sensitivity analyses with three methods in addition to the main analysis by multivariate generalized autoregressive conditional heteroscedasticity (GARCH) approach, supported the findings in this study.
- The limitation of this study was its analysis of a single center with a single ethnicity.

## Introduction

Catastrophic earthquake activity has been reported to exert a variety of effects on both physical and mental health <sup>1</sup>. A previous study reported that approximately 42.6% of victims exhibited moderate to serious mental health problems after the Great East Japan earthquake, which occurred in March 2011 <sup>1</sup>. Acute health effects associated with earthquake activity include acute stress disorders <sup>2</sup>, delirium, <sup>3</sup> and acute and transient psychotic disorders. Longer-term effects on victims' well-being have also been reported, including post-traumatic stress disorder and exacerbation of bipolar disorder <sup>4-6</sup>. Although most previous research has been limited to the health impacts of rare catastrophic earthquakes, very few studies have focused on the health effects associated with substantially more common mild to moderate earthquakes.

Substance abuse is a common disorder reported in the setting of catastrophic disasters <sup>7,8</sup>. Several studies have explored this relationship with regard to alcohol use behaviors <sup>9,10</sup>, with several previous studies reporting an increased prevalence of alcohol abuse after major earthquakes. <sup>11,12</sup> However, in the larger context of catastrophic phenomena, this association remains unclear, with one report showing only a 2% increase in prevalence after a major hurricane <sup>13</sup> and other studies reporting a slight decrease in alcohol abuse after instances of terrorism <sup>9,14</sup>. Moreover, some suggested that disasters have rarely increased the prevalence of substance use disorders. Instead, increased alcohol abuse after disaster can often reflect an exacerbation of existing abuse rather than new-onset disorders <sup>15</sup>. As such, the effect of disasters on alcohol abuse remains controversial. Previous studies have suggested that gender, age, education, and even cultural background modify these associations. <sup>16,17</sup>

Japan is a tectonically active country where earthquakes are observed frequently. The Japan Meteorological Agency observed 2,025 earthquakes in 2017, and more than 6,500 earthquakes were

97 observed in 2016 in Japan <sup>18</sup>. Among the 76 earthquakes in 2017 and 123 events in 2016, 3.8% and 1.9%,  
98 respectively, were greater than a magnitude of 5. In addition to the incidence of earthquakes, the Japan  
99 Meteorological Agency recorded the date, time, magnitude, location, and seismic intensity <sup>19</sup>. Thus, the aim  
100 of this study was to evaluate the same-day association between mild to moderate earthquakes and unhealthy  
101 alcohol use behavior in Japan.

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## 102 **Methods**

### 103 *Study design and cohort description*

104 We conducted a retrospective daily time series study using medical record data from St. Luke's  
105 International Hospital in Tokyo, Japan from April 2004 to March 2017. We included all patients who were  
106 20 or older and presented to the hospital emergency room with acute alcohol intoxication. We excluded all  
107 patients who signed opt-out agreements for their anonymized data to be used in research. In addition,  
108 patients presenting with an altered mental status of uncertain origin were excluded. Our outcome was a  
109 patient volume of acutely intoxicated patients per 24-hour period. Outcomes were compared between days  
110 with and without earthquakes, as observed by the Japan Meteorological Agency.

### 111 *Patient and Public Involvement*

112 There was no involvement of patients other than this data and the public.

### 113 *Research ethics application*

114 The ethical committee at St. Luke's International Hospital approved this study (approval number:  
115 17-R025).

### 116 *Data availability statement*

117 No additional data available.

### 118 *Acute alcohol intoxication*

119 Emergency physicians at the hospital clinically diagnosed with acute alcohol intoxication based on  
120 testimonies by patients or their companions. A blood ethanol level of 100 mg/dl or higher was used to  
121 support the diagnosis for those whose testimonies could not be elicited directly<sup>20</sup>.

## Earthquake

All earthquake data were obtained from the Japan Meteorological Agency<sup>18</sup>. The recorded data contain the time and date of occurrence, the Richter magnitude, the depth of epicenter, and Shindo scale data for any earthquake detected. With a range of 0 to 7, Shindo is the unique measurement scale used in Japan for seismic intensities in a specific area<sup>19</sup>. Unlike the Richter scale, which represents the size of the earthquake itself and is unique for each earthquake, Shindo scaling reflects the intensity of the observed shaking in a given area and is based on the distance from the epicenter at which the seismic activity was observed. Generally speaking, the further the observed area is from the epicenter, the lower the Shindo measurement is for that area. A Shindo score of 1 is comparable to mild shaking observed only when sitting quietly in a structure, while a Shindo score of 4 is defined as observable shaking that is intense enough to startle, awaken people from sleep, and can be detected while walking. A Shindo score of 7 equates to severe shaking in which it is impossible to remain standing or move without crawling. In terms of the severity of the earthquake, we defined earthquakes with a Shindo score of 1 – 3 as mild to moderate earthquakes and those with a Shindo score of 4 or more as severe earthquakes. We defined a daytime earthquake as one observed between 9 a.m. and 5 p.m., while a nighttime earthquake was defined as occurring between 5 p.m. and 12 a.m. The reason why we divided earthquakes as above is that a daytime earthquake was believed to affect the subsequent drinking behavior on the same night. In contrast, a nighttime earthquake that may have occurred while drinking alcohol was believed to have a different effect on drinking behavior. The remaining time period, from 12 a.m. to 9 a.m., was considered as having little effect on alcohol behavior.



143 *Study site*

144 St. Luke's International Hospital is located in Chuo-ku, Tokyo, Japan. The hospital, a 520-bed  
145 tertiary-level community teaching hospital, accepts more than 10,000 ambulance admissions a year. Located  
146 close to Ginza, a major entertainment district popular for bars and restaurants serving alcohol, St. Luke's  
147 receives the largest number of ambulances per year, including approximately 50% of ambulances dispatched  
148 from the Ginza area. We included only earthquakes that were observed in this metropolitan Tokyo area in  
149 the analyses.

150  
151 *Category of the day in relation to work week and seasonality*

152 Because the incidence of acute alcohol intoxication is considered to vary substantially by the day of  
153 the week, we divided the days into three categories: weekdays, days prior to a non-working day, and non-  
154 working days (generally understood in Japan to be Saturday, Sunday, and designated national holidays). For  
155 days overlapping categories, we considered days prior to a non-working day the most dominant. For  
156 instance, because December 31, January 1st, 2nd, and 3rd are designated national holidays in Japan, we  
157 categorized December 31, January 1st and 2nd as "days prior to a non-working day", and 3rd as a "non-  
158 working day".

159 As the incidence of acute alcohol intoxication is also considered to be related to seasonality, we  
160 categorized March, April and May as spring; June, July and August as summer; September, October and  
161 November as fall; December, January and February as winter.

162  
163 *Statistical analyses*

164 Because the occurrence of earthquakes on a certain day was considered to be autocorrelated and  
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165 have an autoregressive conditional heteroscedasticity (ARCH) effect (Figure), we applied a multivariate  
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166 generalized autoregressive conditional heteroscedasticity (GARCH) approach with dynamic conditional  
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167 correlation to investigate the association between patients' presentation in the ER and acute alcohol  
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168 intoxication and occurrence of earthquakes <sup>21-23</sup>. In terms of the primary outcome, we first applied a simple  
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169 GARCH model with each variable examining the relationship between hospital admission for acute alcohol  
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170 intoxication and earthquake activity, the category of day, and seasonality. This was followed by a  
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171 multivariate GARCH(1,1) model with variables found to have a *p* value of 0.2 or lower in the simple  
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172 GARCH model, as well as a year-fixed effect and changes in alcohol taxation. Alcohol taxation had changed  
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173 five times during study periods, and it is included the model as a categorical variable. Because the taxation  
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174 rates were similar during the study periods (e.g., 45.1%- 46.6% for beer, 16.2%-18.1% for sake), the impact  
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175 of alcohol taxation change on the results was considered to be limited. The  $\beta$  coefficient and 95% confidence  
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176 intervals (CI) were calculated. In addition, we stratified the analyses by both gender and age (50 years or  
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177 older versus less than 50 years). Moreover, we separately analyzed data before the Great East Japan  
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178 earthquake on March 11, 2011 and after the earthquake. We also conducted sensitivity analyses to check  
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179 robustness with the following three methods: using the Richter scale magnitude as a covariate to evaluate  
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180 whether the results differ according to the magnitude of the earthquake; introducing different lag times  
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181 between the earthquake and hospital visits (e.g., 1, 3 or 7 days after the earthquakes), excluding days in  
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182 which severe earthquakes (Shindo scale  $\geq 4$ ) occurred; and having the data stratified by day of the week. All  
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183 analyses were performed using Stata 14.0 (Stata Corp, TX, USA).  
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60  
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## Results

During the study period, earthquakes were observed 706 times with a median Shindo score in the catchment area of 2 (interquartile range 1). During the 4,747 days in the study period, earthquakes were observed on 500 days. During this period, 6,571 patients were extracted from the electronic medical record. Among them, 99 were excluded because they were younger than 20 years old, and 77 were excluded based on the blood alcohol level. Finally, 6,395 patients with a mean age of 42.6 (*SD* 16.9) were treated for acute ethanol intoxication; 4,592 (71.8%) were male (Table 1).

Table 2 shows the results for the number of patients with acute ethanol intoxication from the simple and multivariate GRACH models. In univariate analyses, the daytime earthquake figure was marginally and inversely related to the number of acutely intoxicated patients ( $\beta$  coefficient: -0.19, 95% CI: -0.40 - 0.01). The number of days prior to a non-working day ( $\beta$  coefficient: 0.26, 95%CI: 0.15 - 0.37) was significantly related and the number of non-working days ( $\beta$  coefficient: 0.08, 95%CI: -0.01 - 0.14) was marginally significantly related to acute intoxication. These findings remained similar in multivariate analyses after adjusting for both occurrences of a daytime earthquake, the category of day, seasonality, year-fixed effect and change in alcohol taxation.

In a sensitivity analysis, including Richter scale magnitude as a covariate to evaluate whether the results differ according to the magnitude of the earthquake, the daytime earthquake number was still marginally related to decreased patient volume ( $\beta$  coefficient: -0.23, 95% CI: -0.47 - 0.01). However, the magnitude of the earthquake itself had no relationship with patient volume ( $\beta$  coefficient: 0.01, 95% CI: -0.02 - 0.04). When we introduced different lag times between the earthquake and hospital visits, the number of daytime earthquakes was also marginally significantly related to decreased patient volume ( $\beta$  coefficient:

-0.18, 95% CI: -0.38 - 0.01 for 1 day after an earthquake;  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 3 days after an earthquake; and  $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02 for 7 days after an earthquake), while different lag times themselves were not associated with patient volume. When we excluded days in which severe earthquakes (Shindo scale  $\geq 4$ ) occurred, the findings were similar [daytime earthquake ( $\beta$  coefficient: -0.18, 95% CI: -0.38 - 0.02)]. In the analyses by stratification of day of the week, the number of daytime earthquakes was not related to patient volume on weekdays ( $\beta$  coefficient: 0.01, 95% CI: -0.28 - 0.30) but tend to be negatively related to patient volume on days off ( $\beta$  coefficient: -0.15, 95% CI: -0.49 - 0.19). The analysis was not concaved in the days prior to days off.

Table 3 shows the result of the number of patients with alcohol intoxication from univariate and multivariate analyses stratified by gender. The inverse association between daytime earthquake and alcohol intoxication seen in a pooled analysis was only observed among men ( $p < 0.03$  for males and  $p = 0.99$  for females). Although a positive association between the day before non-working days and acute alcohol intoxication were observed in both males ( $p < 0.01$ ) and females ( $p < 0.01$ ), higher rates of intoxication on non-working days were only observed in women ( $p = 0.02$  for females and  $p = 0.35$  for males). Among male patients, the number of patients with acute alcohol intoxication rose in the winter compared to spring ( $p = 0.01$ ), but not among females ( $p = 0.42$ ).

Table 4 shows the result for the number of patients with alcohol intoxication from univariate and multivariate analyses stratified by age group. Older people were less likely to be admitted to the ER due to acute alcohol intoxication on days when daytime earthquakes occurred ( $p = 0.11$ ), but the same pattern was not seen among younger people ( $p = 0.36$ ). Both older and younger patients with acute alcohol intoxication were more likely to be admitted on days before non-working days as well as on non-working days compared

to weekdays. However, in terms of seasonality, older people were significantly more likely to be admitted to the ER with acute alcohol intoxication in the winter ( $p<0.01$ ), but not younger people ( $p=0.83$ )

In terms of stratification by the date of the Great East Japan earthquake, the number of daytime earthquakes was inversely related to the number of acutely intoxicated patients after the Great East Japan earthquake ( $\beta$  coefficient: -0.28, 95% CI: -0.55 - -0.02), while the number of daytime earthquakes was not related to the number before the Great East Japan earthquake ( $\beta$  coefficient: -0.02, 95% CI: -0.32 - 0.29).

### **Discussion**

Our study found several predictors of the number of intoxicated patients presenting in the ER of a major urban hospital in Japan. Notably, there was an inverse relationship between the number of intoxicated patients and daytime earthquakes observed in older patients and men.

Although previous studies that evaluated drinking behavior after catastrophic earthquakes reported both positive and negative effects, we found that non-catastrophic earthquakes may exert a dampening (i.e., a health-favorable) effect on excess alcohol consumption. This finding was considered to be a type of stress-related growth, which is the theory that people develop from negative events<sup>24</sup>. We speculate that people may avoid risky behaviors, such as going out with companions after work, to indulge in excessive amounts of drinking immediately after an earthquake. When people experience earthquakes, many may suspect additional tectonic activity; multiple earthquakes in a single day are common and were observed on 83 (16.7%) days in our study. As a result, we suspect that many people choose to go home rather than go out, as has been documented in reports about catastrophic earthquakes<sup>25</sup>. People may avoid social activities, such as after-work gatherings, on days in which even mild but nevertheless frightening natural phenomena have occurred, thereby reducing the opportunities for excessive drinking and other risky social behaviors. Lower

248 blood alcohol levels noted on earthquake days also suggest that even imbibers may limit the amount of  
2 alcohol consumed on such days. Similar social behaviors have been observed after the Great East Japan  
3 earthquake in 2011, although whether these behavioral changes are conscious or unconscious remains  
4 unclear<sup>26</sup>.

252 We found both age and gender differences in the relationship between daytime earthquakes and  
14 acute alcohol intoxication. There were statistically fewer male patients with acute alcohol intoxication on  
15 days when a daytime earthquake occurred compared to days without seismic activity. Interestingly, this  
16 relationship was not found for female patients. A previous systematic review reported that differing patterns  
17 of alcohol use between men and women are driven by both biological and psycho-socio-cultural factors<sup>27</sup>.  
18 As a result, men are more likely to seek sensations, including hazardous drinking, than women in ordinary  
19 settings<sup>28,29</sup>. However, it is possible that mild earthquakes may affect these psycho-socio-cultural factors  
20 more for men than women. Social capital may play an important role in this<sup>30</sup>. Because most Japanese male  
21 workers drink with colleagues after work<sup>31</sup>, some may suggest that others not go out to drink after work on  
22 days with earthquakes.

262 In terms of age, fewer older patients with acute alcohol intoxication were observed on days with  
44 earthquakes, despite an unchanged number of younger patients presenting with acute alcohol intoxication on  
45 these days. A previous survey about alcohol use reported that younger people tended to indulge in more  
46 binge drinking and heavy episodic drinking in Japan<sup>32</sup> and other countries<sup>33</sup>. Psychologically disturbing  
47 natural phenomena, however mild, may also exert specific inhibitory psycho-socio-cultural effects on risky  
48 behaviors of younger people. Further research is needed to evaluate the potential mechanisms for these  
49 differences.

269 Significantly fewer patients with acute alcohol intoxication were observed on days with daytime  
270 earthquakes compared to those on days without daytime earthquakes after the Great East Japan earthquake,  
271 while the finding was not observed before the Great East Japan earthquake. This suggests that people still  
272 have catastrophic earthquakes in mind and avoid sensation seeking from stress-related growth.

273 Our study has some limitations. First, not all potential patients with acute alcohol intoxication  
274 were transferred to our hospital, resulting in a measure of selection bias. However, because our hospital has  
275 the largest number and highest rate of ambulance acceptances in Tokyo, with more than 50% of ambulances  
276 dispatched to the local entertainment area were transferred to us, and we assume that this bias is neither  
277 large nor differential. In addition, the findings may not be applicable to other countries because ethnicity and  
278 cultural diversity could exist<sup>34</sup>. Second, because we were unable to accurately record information about  
279 when patients started to consume alcohol, precise knowledge of the temporal relationship between alcohol  
280 consumption, intoxication, and earthquakes are difficult to assess. Similarly, because qualitative data  
281 concerning patients' physical and emotional perception of seismic activity is not available, further studies  
282 are warranted in this area. In addition, evaluation for acute stress disorder may be useful to explain the  
283 gender and age difference of findings. Finally, an earthquake itself may somewhat impact hospital  
284 operations. However, the emergency department of hospitals had operated as usual on and after the Great  
285 East Japan earthquake. Therefore, the impact is considered to be limited.

**Conclusion**

On days when mild to moderate daytime earthquakes occurred, our hospital had fewer patients with acute alcohol intoxication presenting in the emergency room. This pattern was also seen for men and elderly patients. Even mild natural phenomena may lead to changes in social behavior that result in avoidance of excessive alcohol use.

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	Patients (n=6,395)
Age, year, mean (SD)	42.6 (16.9)
Male, n (%)	4,592 (71.8)
Blood alcohol level, mg/dl, mean (SD)	225.4 (87.2)
Type of day when the patient visited the hospital	
Weekdays, n (%)	3,125 (48.9)
Days prior to day off, n (%)	1,220 (19.1)
Day off, n (%)	2,050 (32.1)
Season in which the patient visited the hospital	
Spring, n (%)	1,562 (24.4)
Summer, n (%)	1,558 (24.4)
Fall, n (%)	1,617 (25.3)
Winter, n (%)	1,658 (25.9)
The occurrence of earthquake when the patient visited the hospital	
A whole day, n (%)	657 (10.3)
Daytime earthquake, n (%)	197 (3.1)
Nighttime earthquake, n (%)	188 (2.94)

Table 1. Patients' characteristics

Variable	Univariate GARCH* model			Multivariate GARCH* model		
	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value	$\beta$ coefficient	95%CI <sup>†</sup>	<i>p</i> value
Earthquake factors						
Incidence of earthquake	0.00	(-0.12 — 0.12)	0.95			
Number of earthquakes a day, times	-0.02	(-0.06 — 0.03)	0.46			
The depth of the epicenter, km	0.00	(-0.01 — 0.01)	0.85			
The highest magnitude in a day	0.00	(-0.02 — 0.02)	0.98			
The highest Shindo in a day	0.00	(-0.08 — 0.07)	0.92			
Daytime earthquake <sup>§</sup>	-0.19	(-0.40 — 0.01)	0.06	-0.18	(-0.38 — 0.02)	0.07
Nighttime earthquake <sup>‡</sup>	0.12	(-0.12 — 0.35)	0.34			
Date						
Categories of day						
Weekday		Reference			Reference	
The day before non-working day	<b>0.26</b>	<b>(0.15 — 0.37)</b>	<b>&lt;0.01</b>	<b>0.25</b>	<b>(0.15 — 0.36)</b>	<b>&lt;0.01</b>
Non-working day	0.08	(-0.01 — 0.17)	0.05	0.08	(-0.01 — 0.16)	0.08
Season						
Spring		Reference			Reference	
Summer	0.02	(-0.09 — 0.13)	0.73	0.02	(-0.09 — 0.12)	0.78
Fall	0.05	(-0.06 — 0.17)	0.35	0.03	(-0.76 — 0.14)	0.55
Winter	0.10	(-0.01 — 0.22)	0.07	<b>0.12</b>	<b>(0.02 — 0.23)</b>	<b>0.02</b>

Table 2.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from the univariate and multivariate GARCH model

\*GARCH stands for generalized autoregressive conditional heteroskedasticity. The multivariate GARCH model was adjusted for variables found to have a *p* value of 0.2 or less in a simple GARCH model as well as year-fixed effect and changes in alcohol taxation.; <sup>†</sup>CI represents confidence interval; <sup>§</sup>Daytime earthquake means that an earthquake was observed between 9 a.m. and 5 p.m.; <sup>‡</sup>Nighttime earthquake means that earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the *p* value is less than 0.05.

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Variable	Male ( <i>n</i> = 4,646)				Female ( <i>n</i> = 1,826)			
	Univariate GARCH*		Multivariate GARCH*		Univariate GARCH*		Multivariate GARCH*	
	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value	$\beta$ coefficient (95%CI <sup>†</sup> )	<i>p</i> value
Earthquake factors								
Incidence of earthquake	0.00 (-0.11 — 0.10)	0.98			-0.01 (-0.07 — 0.05)	0.86		
Number of earthquakes per day, times	-0.01 (-0.05 — 0.02)	0.39			0.00 (-0.02 — 0.02)	0.79		
The depth of the epicenter, km	0.00 (-0.00 — 0.00)	0.98			0.00 (-0.01 — 0.01)	0.78		
The highest magnitude in a day	0.00 (-0.02 — 0.02)	0.98			0.00 (-0.01 — 0.01)	0.98		
The highest Shindo in a day	-0.01 (-0.07 — 0.05)	0.81			0.00 (-0.03 — 0.04)	0.94		
Daytime earthquake <sup>§</sup>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.02</b>	<b>-0.19</b> <b>(-0.36 — -0.02)</b>	<b>0.03</b>	0.00 (-0.09 — 0.10)	0.95	0.00 (-0.10 — 0.10)	0.99
Nighttime earthquake <sup>‡</sup>	0.05 (-0.14 — 0.25)	0.59			0.05 (-0.07 — 0.16)	0.41		
Date								
Categories of day								
Weekday		Reference				Reference		
The day before a non-working day	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.19</b> (0.10 — 0.28)	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>	<b>0.08</b> <b>(0.03 — 0.13)</b>	<b>&lt;0.01</b>
Non-working day	0.04 (-0.04 — 0.11)	0.34	0.04 (-0.04 — 0.11)	0.35	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>	<b>0.05</b> <b>(0.01 — 0.09)</b>	<b>0.02</b>
Season								



		Reference		Reference		Reference	
1	Spring						
2		-0.00		-0.00		0.02	0.02
3		(-0.10 — 0.09)	0.93	(-0.10 — 0.09)	0.93	(-0.03 — 0.07)	0.42
4	Summer						0.37
5		0.02		0.02		0.02	0.01
6		(-0.07 — 0.12)	0.63	(-0.08 — 0.11)	0.74	(-0.04 — 0.07)	0.55
7	Fall						0.58
8		<b>0.12</b>		<b>0.12</b>		-0.02	-0.02
9		<b>(0.02 — 0.21)</b>	<b>0.01</b>	<b>(0.02 — 0.21)</b>	<b>0.01</b>	(-0.07 — 0.03)	0.43
10	Winter						0.42

Table 3.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from the univariate and multivariate GARCH model by gender

\*GARCH represents generalized autoregressive conditional heteroskedasticity. The multivariate GARCH model was adjusted for variables found to have  $p$  value of 0.2 or less in a simple GARCH model as well as year-fixed effect and changes in alcohol taxation; †CI represents confidence interval; §Daytime earthquake means that earthquake was observed between 9 a.m. and 5 p.m.; ‡Nighttime earthquake means that earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the  $p$  value is less than 0.05.

50 years or older ( $n = 2,202$ )Younger than 50 years ( $n = 4,270$ )

Univariate GARCH\*

Multivariate GARCH\*

Univariate GARCH\*

Multivariate GARCH\*

 $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value $\beta$  coefficient  
(95%CI<sup>†</sup>) $p$  value

Variable

## Earthquake factors

	-0.03	0.37			0.03	0.54		
Incidence of earthquake	(-0.10 — 0.04)				(-0.07 — 0.13)			
	-0.01	0.35			0.00	0.82		
Number of earthquakes per day, times	(-0.03 — 0.01)				(-0.04 — 0.03)			
	0.00	0.67			0.00	0.98		
The depth of the epicenter, km	(-0.00 — 0.00)				(-0.01 — 0.01)			
	-0.01	0.39			0.01	0.54		
The highest magnitude in a day	(-0.02 — 0.01)				(-0.01 — 0.03)			
	-0.02	0.35			0.02	0.58		
The highest Shindo in a day	(-0.06 — 0.02)				(-0.04 — 0.08)			
	-0.09	0.09	-0.09	0.11	-0.07	0.39	-0.08	0.36
Daytime earthquake <sup>§</sup>	(-0.20 — 0.01)		(-0.19 — 0.02)		(-0.23 — 0.10)		(-0.24 — 0.09)	
	0.03	0.65			0.09	0.32		
Nighttime earthquake <sup>‡</sup>	(-0.09 — 0.15)				(-0.09 — 0.28)			

## Date

## Categories of day

Weekday		Reference				Reference		
The day before the non-working day	<b>0.06</b>	<b>0.02</b>	<b>0.06</b>	<b>0.03</b>	<b>0.19</b>	<b>&lt;0.01</b>	<b>0.19</b>	<b>&lt;0.01</b>
	(0.01 — 0.12)		(0.01 — 0.12)		( <b>0.11 — 0.28</b> )		( <b>0.11 — 0.28</b> )	
Non-working day	-0.04	0.09	-0.04	0.08	<b>0.11</b>	<b>&lt;0.01</b>	<b>0.11</b>	<b>&lt;0.01</b>
	(-0.08 — 0.01)		(-0.09 — 0.01)		( <b>0.04 — 0.18</b> )		( <b>0.05 — 0.18</b> )	

## Season

		Reference		Reference		Reference		Reference
1	Spring							
2		-0.03		-0.03		0.06		0.06
3		(-0.09 — 0.02)	0.26	(-0.09 — 0.02)	0.23	(-0.03 — 0.14)	0.20	(-0.03 — 0.15) 0.17
4	Summer							
5		0.01		0.01		0.04		0.03
6		(-0.05 — 0.07)	0.73	(-0.05 — 0.06)	0.82	(-0.05 — 0.12)	0.40	(-0.05 — 0.12) 0.45
7	Fall							
8		<b>0.10</b>		<b>0.10</b>		0.01		0.01
9		<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	<b>(0.04 — 0.15)</b>	<b>&lt;0.01</b>	(-0.08 — 0.10)	0.81	(-0.08 — 0.79) 0.83
10	Winter							

Table 4.  $\beta$  coefficients for the number of patients with acute ethanol intoxication from univariate and multivariate GARCH model by age

\*GARCH stands for generalized autoregressive conditional heteroskedasticity; †CI represents confidence interval; §Daytime earthquake means that the earthquake was observed between 9 a.m. and 5 p.m.; ‡Nighttime earthquake means that the earthquake was observed between 5 p.m. and 12 p.m.

Numbers in bold indicate that the p value is less than 0.05.

1 **Figure legend:**  
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4 Figure 1. The number of earthquakes per day.  
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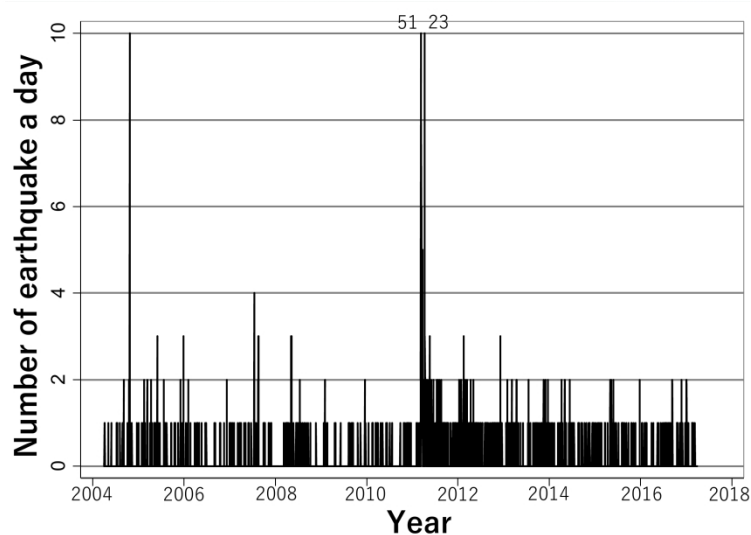


Figure 1. Daily number of earthquake.

279x215mm (300 x 300 DPI)

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

Check	Page, session		Item No	Recommendation
X	Page1. Title	<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
X	Page2-3, abstract			(b) Provide in the abstract an informative and balanced summary of what was done and what was found
<b>Introduction</b>				
X	Page4-5, introduction	Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
X	Page5, last in Introduction	Objectives	3	State specific objectives, including any prespecified hypotheses
<b>Methods</b>				
X	Page6, first paragraph in Methods	Study design	4	Present key elements of study design early in the paper
X	Page6, first paragraph in Methods	Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
X	Page6, first paragraph in Methods	Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
X	Page6, first and second paragraph in Methods			(b) For matched studies, give matching criteria and number of exposed and unexposed
X	Page7-8, third paragraph in Methods	Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
X	Page7-8, third paragraph in Methods	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
X	Page7-8, third paragraph in Methods	Bias	9	Describe any efforts to address potential sources of bias
X	Page9, third paragraph in statistical analyses	Study size	10	Explain how the study size was arrived at
X	Page8, first and second paragraph in statistical analyses	Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

1	X	Page8, first and second paragraph in statistical analyses	Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
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4	X	Page8, first and second paragraph in statistical analyses			(b) Describe any methods used to examine subgroups and interactions
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8	X	Page8, first and second paragraph in statistical analyses			(c) Explain how missing data were addressed
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11	X	N/A			(d) If applicable, explain how loss to follow-up was addressed
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14	X	Page8, first and second paragraph in statistical analyses			(e) Describe any sensitivity analyses
15					
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18			<b>Results</b>		
19	X	Page10, result session	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
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25	X	Page10, result session			(b) Give reasons for non-participation at each stage
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27	X	N/A			(c) Consider use of a flow diagram
28					
29	X	Page10, result session	Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
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33	X	Page10, result session			(b) Indicate number of participants with missing data for each variable of interest
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35	X	Page10, result session			(c) Summarise follow-up time (eg, average and total amount)
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37					
38	X	Page10, result session, table1	Outcome data	15*	Report numbers of outcome events or summary measures over time
39					
40	X	Page10-11, result session	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
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47	X	Page10-11, result session			(b) Report category boundaries when continuous variables were categorized
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49	X	Page10-11, result session			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
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53	X	Page10-11, result session, Table2.	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
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57			<b>Discussion</b>		
58	X	Page12, first	Key results	18	Summarise key results with reference to
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1		paragraph in			study objectives
2		discussion			
3	X	Page 12-14 in	Limitations	19	Discuss limitations of the study, taking
4		discussion			into account sources of potential bias or
5					imprecision. Discuss both direction and
6					magnitude of any potential bias
7					
8	X	Page 14	Interpretation	20	Give a cautious overall interpretation of
9					results considering objectives,
10					limitations, multiplicity of analyses,
11					results from similar studies, and other
12					relevant evidence
13					
14	X	Page 14	Generalisability	21	Discuss the generalisability (external
15					validity) of the study results
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17			<b>Other information</b>		
18	X	Page 1	Funding	22	Give the source of funding and the role
19					of the funders for the present study and,
20					if applicable, for the original study on
21					which the present article is based
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\*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>.