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Clinical Features of Disaster-Associated Direct Deaths during Recent Inland Earthquakes in Japan

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Natural disasters, including earthquakes, cause disaster-associated direct deaths due to hazards and disaster-related deaths. This study was a retrospective and observational study that explored the effect of natural disasters on direct death. Although research reports on disaster-related deaths are common, there are few reports of disaster-associated direct death caused by events, such as house collapses, fires, and sediment-related factors. The amendment of the Building Standards Law in 1981 has made Japanese building standards more stringent. We sought to examine the determinants of the number of disaster-associated direct deaths during recent inland earthquakes in Japan. Following 2016 Kumamoto earthquakes (April 14, 21:26 [magnitude (M) 6.5], April 15, 0:03 [M 6.4], and April 16, 1:25 [M 7.3] and the subsequent numerous aftershocks), police necropsies confirmed 50 disaster-associated direct deaths (28 women [56%]). Thirty-four victims (68%) were elderly people 65 years of age or older, and 38 victims (76%) died as a result of a collapsed house. These percentages are consistent with those associated with recent inland earthquake disasters in Japan. The main finding was a linear correlation between the number of completely collapsed houses and the number of deaths due to house collapse during recent inland earthquakes in Japan (P = 0.02). It is suggested that the maintenance of houses may be important in reducing the number of disaster-associated direct deaths during inland earthquakes. The amendment of the Building Standards Law might reduce the number of disaster-associated direct deaths during inland earthquakes.

Keywords: direct death; disaster; earthquake; house collapse; house collapse death
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Introduction

Natural disasters including earthquakes cause disaster-associated direct deaths due to hazards and disaster-related deaths due to evacuation and other factors (Ichiseki 2013; Sueta et al. 2019); moreover, the occurrence processes that cause disaster-associated direct deaths and disaster-related deaths and their corresponding countermeasures are significantly different.

Disaster-associated direct deaths from earthquakes include death as a result of collapse (those who died due to the collapse of structures or falling elements, the falling of furniture, etc.), fires (those who were involved in fires and burned), sediment (those who died due from being buried alive by landslides, debris flows, landslides, etc., or by structures destroyed by these events) and other/unknown causes (those who are difficult to include in other classifications, such as falling from a high place (e.g., a bridge) due to shaking). It is believed that the occurrence processes responsible for direct deaths are likely to fluctuate due to a variety of complicated factors, and thus, it is necessary to obtain an objective description of the actual situation in individual disaster cases, but there are few reports on the clinical characteristics of victims involved in such disasters.

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On June 1, 1981, the earthquake-resistant design method was significantly revised following the Miyagiken-oki Earthquake that occurred in 1978. This revision was a major amendment of the Building Standards Law. The changes were to use reinforced concrete foundations on soft ground and to double the number of load-bearing walls stipulated by the 1950 Building Standards Law.

The Kumamoto earthquakes, which consisted of magnitude (M) 7 earthquakes and numerous subsequent aftershocks, occurred in April 2016 (Sueta et al. 2017, 2018; Sato et al. 2019; Komorita et al. 2020). We have already reported the characteristics of 197 disaster-related cases if death associated with the 2016 Kumamoto earthquakes (Sueta et al. 2019). The most memorable event for all Japanese people would be the 3.11 Great East Japan Earthquake (GEJE) in 2011 (Ichiseki 2013; Suda et al. 2019). However, we could not obtain any reliable data on direct deaths, excluding those of the tsunami victims, during the GEJE. Moreover, in the present study, since we are referring to the relationship between the number of collapsed houses and the number of direct deaths, we considered only inland earthquakes. Hence, this paper discusses the characteristics of the victims of direct death during earthquakes and the overall number of victims in comparison with the number of victims associated with recent inland earthquakes in Japan.

Methods

The current study was a retrospective and observational study that explored the effect of natural disasters such as the Kumamoto earthquakes on direct death. The study was registered in the University Hospital Medical Information Network Clinical Trial Registry (UMIN000023864): University Hospital Medical Information Network (UMIN)-CTR (http://www.umin.ac.jp/ctr/).

Ethics statement

All procedures were conducted in accordance with the Declaration of Helsinki and its amendments. The study protocol was approved by the institutional review board of Kumamoto University (Approval No. Rinri 1177).

Study population

Kumamoto Prefecture reported 50 direct deaths. Kumamoto Prefecture examined all 50 cases of postdisaster deaths that were confirmed in police necropsies. We compared the results with those of direct deaths after the Iwate/Miyagi inland earthquake (2008), the Niigata-ken Chuetsu-Oki earthquake (2007), the Niigata-ken Chuetsu earthquake (2004) and the Great Hanshin/Awaji earthquake (1995) (Fire and Disaster Management Agency 2019; Ushiyama and Ohta 2009).

2016 Kumamoto earthquakes

Kumamoto Prefecture is located in southwestern Japan. The Kumamoto earthquakes (Japan Meteorological Agency) occurred in April 2016, including M 7 earthquakes and numerous subsequent aftershocks [specifically, April 14 (21:26 M 6.5 and 22:07 M 5.8), April 15 (0:03 M 6.4) and April 16 (1:25 M 7.3, 1:45 M 5.9, 3:55 M 5.8 and 9:48 M 5.4)]. Regarding the characteristics of the Kumamoto earthquakes, the number of aftershocks that occurred at night was very high. We have already reported the occurrence of venous thromboembolisms(Sueta et al. 2017, 2018), cardiovascular diseases (Komorita et al. 2020) and disaster-related death (Sueta et al. 2019) during the Kumamoto earthquakes.

Statistical analysis

We performed linear regression analyses. A P-value of less than 0.05 indicated statistical significance. Statistical analyses were performed with SPSS version 26 (IBM Inc., Armonk, NY, USA).

Results

Characteristics of the victims

As shown in Fig. 1A, the number of women was 28 (56%), and the number of female victims was slightly higher. Fig. 1B shows the age of the victims classified using the age of 65 as a threshold. Thirty-four of the fifty victims (68%) were 65 years of age old or older, and elderly people were the most likely to die.

All of the victims' addresses were in Kumamoto Prefecture (details not shown). As shown in Fig. 1C, 9 people died on April 14, 2016, and 41 people died on April 16, 2016.

Number of victims by cause of death

As shown in Fig. 1D, police necropsies revealed that the causes of death for the 50 victims were excessive pressure (n = 21), suffocation (n = 13), traumatic shock (n = 6), brain contusion (n = 2), multiple trauma (n = 1), and other/unknown (n = 6).

Number of victims classified by situation

Fig. 1E shows the numbers of victims categorized according to the underlying phenomena. As a result, the 50 victims were classified according to death as a result of house collapse (n = 38), sediment-related disaster (n = 10), fire (n = 1), and other causes (n = 1).

Comparison with recent inland earthquakes in Japan

Table 1 shows a comparison with the damage caused by recent inland earthquakes in Japan. As shown in Table 1, during the 2016 Kumamoto earthquakes, the majority of victims tended to be classified as having died as a result of house collapse, as was the case in the 1995 Great Hanshin-Awaji Earthquake, the 2004 Niigata-ken Chuetsu Earthquake, and the 2007 Niigata-ken Chuetsu-oki Earthquake, which caused damage to the living areas of houses.

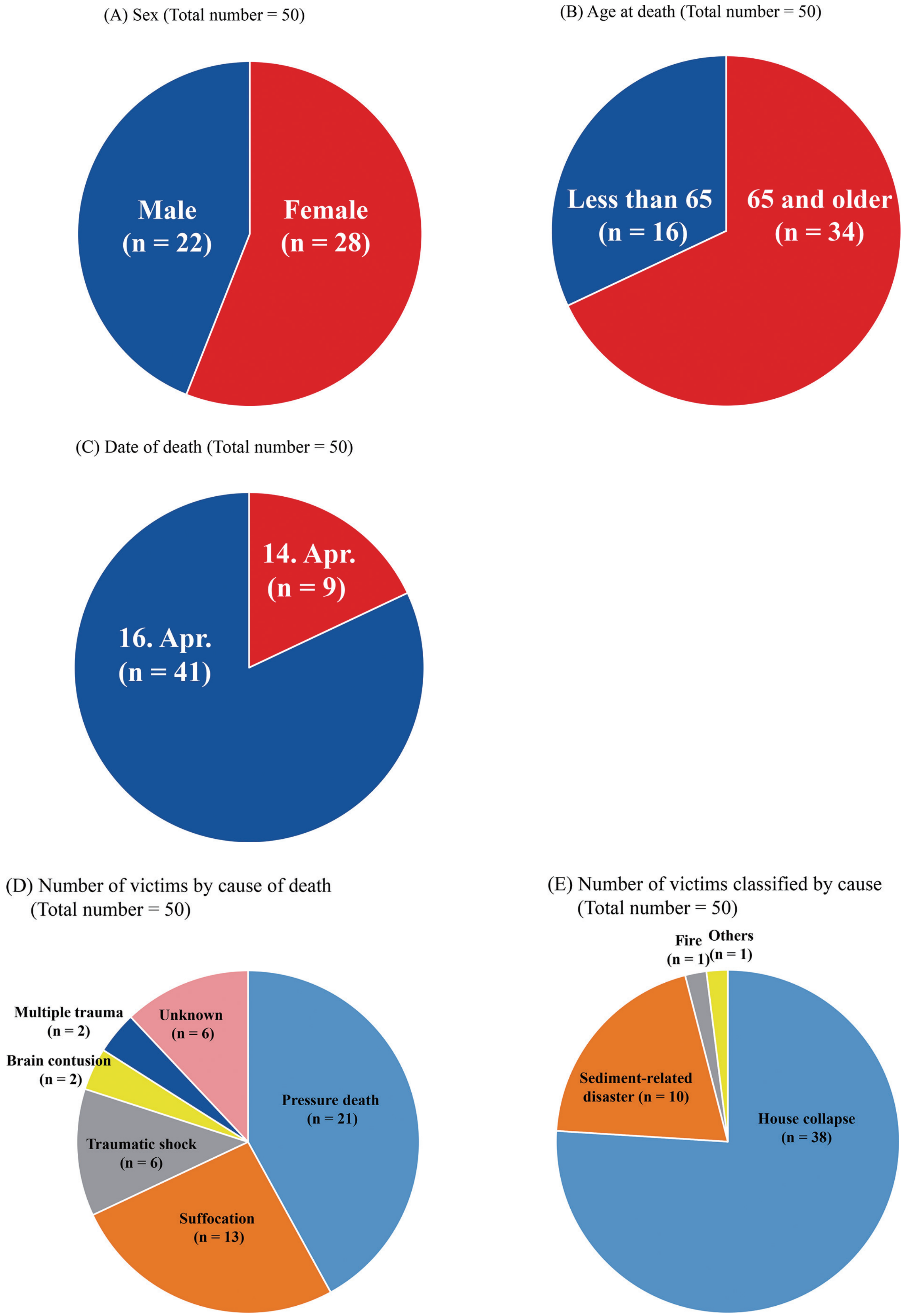

Fig. 1. Characteristics of the victims of disaster-associated direct deaths during the 2016 Kumamoto earthquake (total number of victims: 50).
(A)Sex, (B) age at death with a threshold of 65, (C) date of death, (D) number of victims by cause of death and (E) number of victims classified by cause.

Table 1. Comparison with the damage caused by recent inland earthquakes.

	2016 Kumamoto	2008 Iwate/Miyagi	2007 Niigata-ken Chuetsu-oki	2004 Niigata-ken Chuetsu	1995 Great Hanshin/Awaji
Total no. of death (D)	50	23	11	16	5,502
House collapse (HD)	38	1	9	10	4,831
Sediment-related	10	17	0	6	0
Fire	1	0	1	0	550
Other/unknown	1	5	1	0	121
House collapse death ratio (HD/D)	0.76	0.04	0.82	0.63	0.88
No. of completely collapsed houses (H)	8,657	30	1,331	3,175	104,906
HD/H ratio	0.00439	0.0333	0.00676	0.00314	0.0461

no., number.

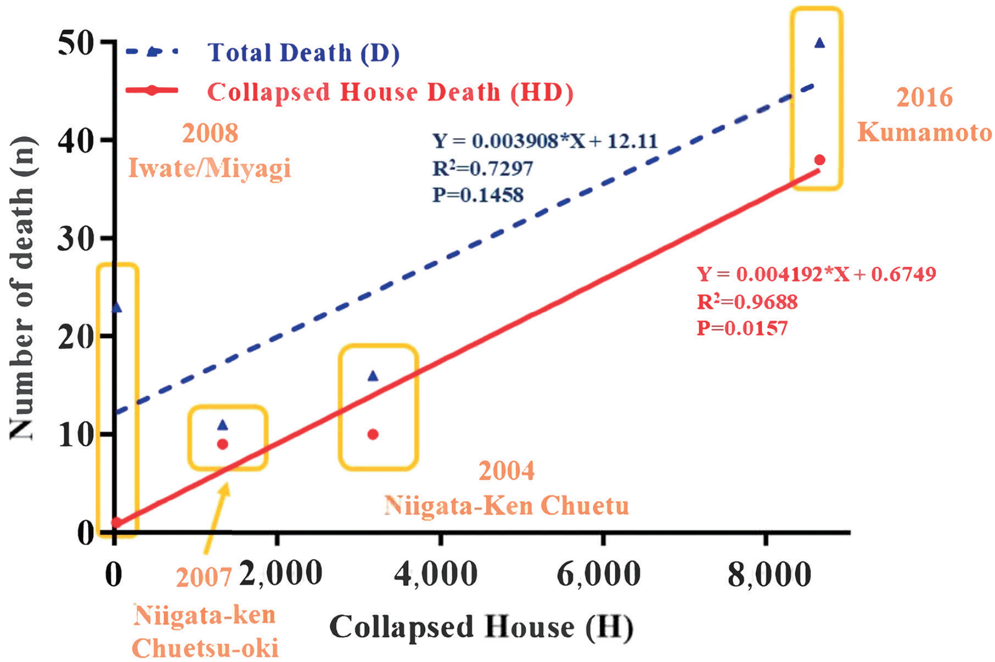

Fig. 2. Linear regressions between the total number of collapsed houses and the overall number of deaths (blue dotted line) and house-collapse deaths (red solid line).
Equations are shown in the figure. X and Y indicate the number of collapsed houses and the number of deaths, respectively. Blue triangles and red circles indicate the number of total deaths and house-collapse deaths, respectively.

Fig. 2 shows the correlations between the total number of collapsed houses and the total number of deaths and house-collapse deaths after inland earthquakes in Japan since 2004. There was a significant correlation between the number of completely collapsed houses and the number of deaths due to house collapse ($P = 0.0157$), despite the very small sample size (Fig. 2). The number of completely collapsed houses and the total number of deaths were strongly correlated ($R^2 = 0.7297$), but the correlation is not statistically significant ($P = 0.1458$).

Discussion

The main feature of the current study was the finding of a linear correlation between the number of completely collapsed houses and the number of deaths due to house collapse during recent inland earthquakes in Japan.

The characteristics of the victims of the Kumamoto earthquake tended to be similar to those of the victims of recent inland earthquakes. It can be inferred that many victims died in old buildings built before the amendment of the Building Standards Law in 1981, when the danger due to earthquake damage was noted because a significant correlation was revealed between the total number of collapsed houses and the number of house-collapse deaths, as the collapse of a residence is the most common cause of direct death in earthquakes. Direct deaths were restricted to two days after the day of the earthquake because it was highly likely that the deaths occurred immediately, given the information shown in Fig. 1E. It is also possible that there is a relationship between the development of the disaster medical system from 1995 to 2016 (the Disaster Medical Assistance Team (DMAT), disaster base hospitals, doctor helicopters, and other organizations) and the reduction of lives lost, that is, the reduction in preventable disaster-associated deaths; however, this conclusion cannot be drawn with certainty because the abovementioned earthquakes occurred in different cities.

In the present study, while there was no significant correlation between the number of completely collapsed houses and the total number of deaths (P = 0.1458), there was a significant correlation between the number of completely collapsed houses and the number of deaths due to house collapse (P = 0.0157, Fig. 2). The discrepancy in the results for the total number of deaths is attributable to the extremely small number of collapsed houses. However, the number of completely collapsed houses and the total number of deaths were strongly correlated (R^2 = 0.7297). Hence, the results of the analysis would be significant if the sample size was larger.

The country of Japan experiences many earthquakes due to its geological characteristics, and there are concerns that massive earthquakes will occur in the future. It may be difficult to achieve "disaster prevention" to prevent disasters, but "disaster mitigation", which involves taking measures to prevent damage in advance, remains important. This paper sought to contribute to this objective.

Most importantly, 76% of the direct deaths during the Kumamoto earthquakes were due to collapsed houses, and the number of house-collapse deaths was found to be related to the number of completely collapsed houses. In other words, the maintenance of houses may be important in reducing the number of direct deaths during inland earthquakes. It is necessary to compare the proportion of collapsed houses during recent inland earthquakes before and after 1981, but the characteristics of the victims of the Kumamoto earthquakes tended to be similar to those of the victims of recent inland earthquakes. Thus, we surmise that the proportion may not change much. Since the proportion of buildings erected before 1981 should decrease in the future, the number of deaths due to house collapse during inland earthquakes is expected to decrease.

In this study, however, the following information was unknown: the ages of the buildings where the victims of collapsed houses were found, the damage status of the collapsed houses with casualties, and the evacuation status after the earthquakes.

In conclusion, we have provided the first report on the victim characteristics associated with inland earthquakes. It is necessary to reaffirm the importance of earthquake "disaster mitigation" measures that have been noted and promoted thus far.

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Conflict of Interest

The authors declare no conflicts of interest.

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