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Factors Affecting Human Damage in Heavy Rains and Typhoon Disasters

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Floods due to heavy rains or typhoons are frequent annual hazards in Japan. This study aims to reduce disaster fatalities and contribute to disaster risk reduction. This retrospective observational study analyzed fatalities caused by heavy rains or typhoons. In Japan, 578 fatalities, related to seven occurrences of heavy rains and 16 typhoons, occurred between 2016 and 2020. Moreover, 13,195 houses collapsed due to hazards. Furthermore, 334 (73.2%) of the 456 fatalities were > 60 years old. Heavy rains caused more local area destruction due to floods and landslides than typhoons although wind- and disaster-related mortalities were found to be caused by typhoons. Human damage was eminent in older people because of their vulnerabilities and possibly dangerous behavior. Many fatalities were due to floods (46.9%) and landslides (44.1%). Indoor and outdoor mortalities due to heavy rains or typhoons were 157 (55.9%) and 124 (44.1%), respectively, and 24 (21.8%) of 124 outdoor mortalities occurred in vehicles. The number of recent flood mortalities in Japan correlates with the number of destroyed houses. Analyzing the victim's locations in the 2020 Kumamoto Heavy Rain using hazard and inundation maps suggested the difficulty of ensuring the safety of people living in dangerous areas. This study showed the characteristics of flood damage by heavy rains and typhoons in Japan and reports that flood damage is increasing because of the hazard size and community aging. Disaster risk reduction, disaster education, and evacuation safety plans for the elderly using hazard maps were important for strengthening disaster resilience.

Keywords: disaster medicine; flood disasters; heavy rain; typhoon; fatalities
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Introduction

Floods are most frequent worldwide. Flood fatalities in 2019 accounted for 43.5% of all hazards, which was the highest by hazard type (CRED 2020). The Representative Concentration Pathways (RCP) 8.5 scenario, which has the highest temperature rise due to global warming, predicts a temperature rise of 2.6-4.8°C in 2100 compared to the reference period (1986-2005 average). The RCP 8.5 scenario showed that 42% of the global land area would increase flood frequency (Hirabayashi et al. 2013). This climate change is already associated with heavy rainfall in Japan. Thus, the current study analyzed heavy rainfall in 2017 and 2018 in Japan and reported that the probability of heavy rainfall every 50 years increased by about 1.5 and 3.3 times compared to the case where global warming was assumed to have no effect (Imada et al. 2020).

The characteristics of Japan's land make it susceptible to heavy rain damage. Moreover, 80% of Japan's land area consists of forests with short and steep rivers. Flood disasters due to heavy rains and typhoons are naturally occurring events that depend on rainfall amounts and rates, area topography, regional land use, soil type of the watershed, and antecedent moisture conditions (Ashley and Ashley

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2008).

According to Cabinet Office data, 23 floods due to heavy rains and typhoons caused human damage in Japan between 2016 and 2020. The flood occurred in July 2020 due to heavy rain, which caused enormous damage, mainly in the southern part of Kumamoto Prefecture (FL-2020-000160-JPN). The 24-h accumulated rainfall was 489.5, 455.5, and 474.5 mm in Yunomae Town, Kuma Village, and Minamata City, respectively. This was currently the highest or equivalent rainfall in these areas in observation history. Heavy rain and flood warnings were issued at 4:50 AM on July 4, 2020 and Kumamoto Prefecture set up an emergency operation center. The Yatsushiro River National Highway Office of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) announced at 5:55 AM that the Kuma River had flooded the Kuma Village. Enormous damage to 4,582 houses (as of January 7, 2021), including 65 fatalities and two missing persons in Kumamoto Prefecture (Cabinet Office 2021a), were noted due to this heavy rain.

This paper aims to show the necessity of ensuring safety in future flood damage based on recent flood fatalities, and contributes to disaster risk reduction in future flood damages. Thus, the characteristics of these fatalities from heavy rains and typhoons were analyzed. In addition, this study was conducted using a hazard map to ensure safety based on the characteristics of the damage caused by the 2020 heavy rain in the southern part of Kumamoto Prefecture, which has detailed information on fatalities.

Few studies in Japan have analyzed flood fatalities. This study aims to contribute to disaster risk reduction by clarifying flood fatality characteristics. Moreover, this is an expected outcome of the Sendai Framework for Disaster Risk Reduction (United Nations 2015).

Methods

Characteristics of recent heavy rain and typhoon fatalities in Japan

The data used in this study were extracted from the Cabinet Office storm and flood damage database and the database of each local government. The database of fatalities caused by floods in Japan was collected between 2016 and 2020. Seven occurrences of heavy rains and 16 typhoons had fatalities (Table 1). Assembled data include the number of fatalities, injured people, and completely collapsed houses. Assembled data of fatalities include age, sex, causes, and places where the victims were discovered. The causes of mortality were categorized into five (Table 2).

Statistical analysis

Data for skewed distribution are expressed as median (interquartile range). Moreover, categorical variables are shown as percentages, and intergroup comparisons were analyzed using the chi-square test.

Linear regression analyses were performed to test the correlation between the number of collapsed houses and human damages. A p value < 0.05 indicated statistical significance, and all tests were two-tailed. The danger areas

Table 1. Damage caused by recent heavy rains and typhoons in Japan.

	Heavy rain	Jul. 2020	Oct. 2019	Aug. 2019	Jun. 2019	Jul. 2018”	Jun. 2017	Jun. 2016
Total no. of completely collapsed houses	8,866	1,621	34	95	9	6,767	325	15
Total no. of fatalities	402	86	14	4	2	245	44	7
Total no. of severe injured people	165	23	5	1	1	123	9	3
Total no. of minor injured people	408	54	8	1	4	309	25	7
Date source		1) ~ 8)	9) ~ 11)	12)	13), 14)	15) ~ 24)	25)	26), 27)
	Typhoon	**#10_2020**	**#19_2019**	**#17_2019**	**#15_2019**	**#10_2019**	**#8_2019**	**#24_2018**
Total no. of completely collapsed houses	4,329	35	3,273		460		1	14
Total no. of fatalities	176	6	94	1	10	2	1	2
Total no. of severe injured people	221	16	42	3	20	7	1	22
Total no. of minor injured people	2,161	95	334	62	139	49	4	173
Date source		28) ~ 30)	9) ~ 11), 31) ~ 38)	39), 40)	11), 41)	42), 43)	44), 45)	46) ~ 48)
	#21_2018	**#21_2017**	**#18_2017**	**#5_2017**	**#16_2016**	**#13_2016**	**#10_2016**	**#9_2016 #11_2016**
Total no. of completely collapsed houses	26	5	3	2	6		502	2
Total no. of fatalities	14	8	5	2	1	1	27	2
Total no. of severe injured people	46	28	8	2	12		5	9
Total no. of minor injured people	897	187	51	49	36	2	10	73
Date source	49) ~ 52)	53), 54)	55)	56)	57)	58)	59), 60)	61)

1)~61) Data source are listed in the Appendix.

Table 2. Five categories of causes of death.

Category 1 Floods	
	The following are applicable: ・Drowning and suffocation due to flood ・Fall to the river and irrigation canals ・Lost person found dead in rivers, sea and paddy fields
Category 2 Landslides	
	The following are applicable: ・Encounter with sediment-related disasters indoors and outdoors ・Things caught in a landslide during work
Category 3 Gusts or strong winds	
	The following are applicable: ・Trauma death that fell due to the wind ・Fall to the sea due to wind
Category 4 Disaster-related death	
	The following are applicable: ・Heat stroke due to power outage ・Cardiopulmonary arrest due to stress ・Exacerbation of pre-existing illness
Category 5 Others	
	The following are applicable: ・Trauma during recovery work ・Trauma death not applicable to categories 1 to 4

are being clarified, (e.g., displaying the maximum inundation assumption on the hazard map) due to the revision of the Flood Control Law in 2015. However, people were killed inside houses due to flooding or sediment-related disasters. Therefore, further justifying the evacuation from the dangerous areas in the event of a flood is possible if a correlation is predicted between the number of completely collapsed houses and the fatalities and if that tendency is shown. Statistical analyses used the Statistical Package for the Social Sciences, version 26 (IBM Inc., Armonk, NY, USA).

Analysis of locations of fatalities in the 2020 Kumamoto Heavy Rains.

The current study analyzes the detailed information on the damage in Kumamoto Prefecture in 2020 due to heavy rain. Fatalities' information reported by Kumamoto Prefecture was used. The Kumamoto Prefecture examined all 65 cases of fatalities that were confirmed in police offices, and individual data on age, sex, location and detailed situation of fatalities (including outdoor/indoor, vehicle usage and occupation) were published. The fatalities' locations were mapped on the inundation estimate map prepared by the Geospatial Information Authority of Japan (GSI 2020). The locations of the fatalities on the actual inundation map (GIS) and possible hazard map were mapped (MLIT 2020). The MLIT hazard map added possible maximum flooding area and cautions of the sediment or landslide risks onto the GSI map. The MLIT map, accessed in September 2020 was used. The inundation hazard map to plot the locations of fatalities was used because the floods were the major reason for mortality in the Hitoyoshi and Kuma areas in Kumamoto Prefecture: *assumed maximum scale* was displayed on the map (MLIT 2020). A sediment hazard map to plot the locations of fatalities was used because the landslides were the major fatality cause in the Ashikita area in Kumamoto Prefecture: *sediment disaster risk area*, *caution area*, and *special caution area* were displayed on the map (MLIT 2020). The fatalities' locations were mapped on them.

Ethics statement

All procedures were conducted following the Declaration of Helsinki and its amendments. The institutional review board of Kumamoto University approved the study protocol (Approval No. Rinri 2194).

Results

Characteristics of fatalities by heavy rains and typhoons in Japan

During the 5 years (2016-2020), 578 fatalities related to seven occurrences of heavy rains and 16 typhoons occurred in Japan, with an average of approximately over 100 fatalities per year. Moreover, 13,195 houses completely collapsed due to these hazards (Table 1). Of the 456 fatalities with known ages, 334 (73.2%) were > 60 years old, which shows that older people can be the victims unproportionally. The age distribution of 447 fatalities was shown in Fig. 1. Nine were excluded because the detailed age is unknown. Of the 367 fatalities with known sexes, 195 (53.1%) were males (Fig. 2A). Fig. 2B shows the number of fatalities due to heavy rains. Fig. 2C shows the number of fatalities due to typhoons. Fig. 2B and C show the possibility of more male fatalities in typhoon disasters, which was not statistically significant.

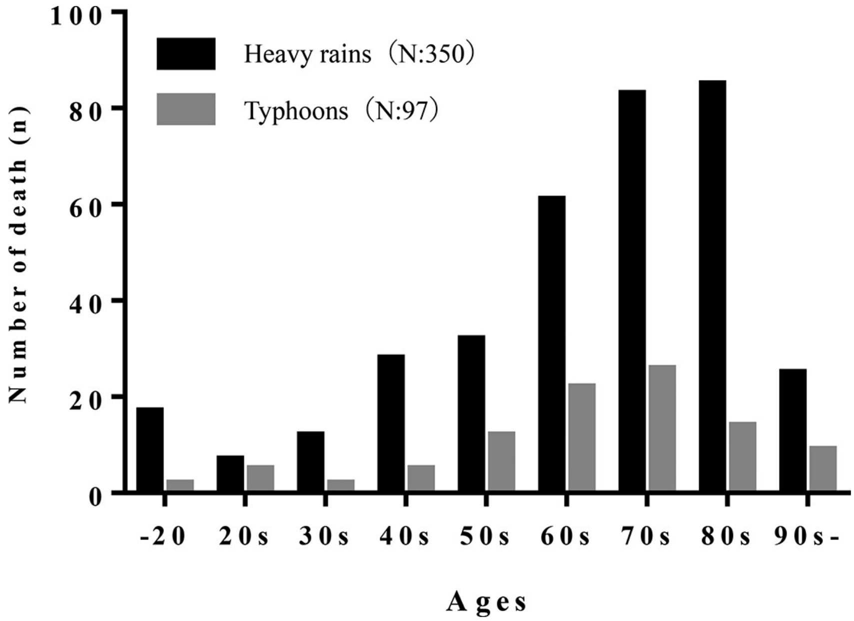

Fig. 1. Age range of the fatalities due to heavy rains and typhoons.
Of the 456 fatalities, 334 (73.2%) were > 60 years old, which shows that elderly people were the most likely to expire.

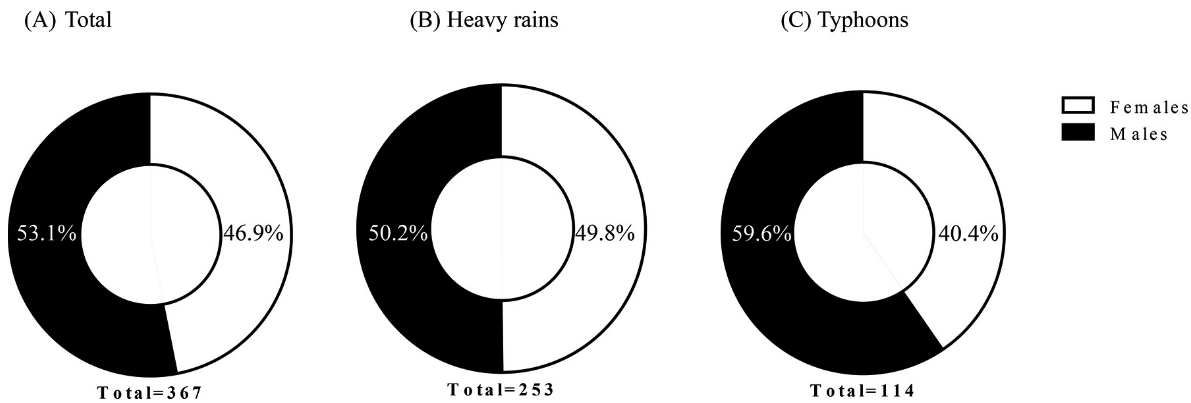

Fig. 2. Sexes of the fatalities in heavy rains and typhoons.
(A) Total number of fatalities due to flood disasters: the number of male fatalities was slightly higher. (B) Heavy rain deaths: no sex difference was found. (C) Typhoon deaths: the number of male fatalities tended to be higher than the number of female fatalities ($p = 0.09$).

Number of fatalities by mortality cause

Fig. 3 shows the number of fatalities categorized according to underlying phenomena. Fig. 3A shows 422 fatalities with known mortality causes. Categories 1 (flood; n = 198, 46.9%) and 2 (landslide; n = 186, 44.1%) accounted for most. Fig. 3B indicates that landslide was the biggest cause of fatalities (n = 169, 53.8%) due to heavy rain. Fig. 3C shows that flood is the biggest cause of fatalities (n = 60, 55.6%). Disaster-related mortalities (n = 15, 13.9%) and few strong wind-related fatalities in typhoons (n = 3, 2.8%) were noted.

Fig. 4A shows the number of fatalities by discovery locations. Fatalities occurred more frequently indoors (n = 157, 55.9%) than outdoors (n = 124, 44.1%). Fig. 4B shows that fatalities caused by heavy rains were notably more frequent indoor (n = 106, 59.6%) than outdoor (n = 72, 40.4%). However, no such difference for typhoon fatalities were noted (Fig. 4C).

Of the 281 total fatalities outdoor, 24 (8.5%) expired inside vehicles. The sex of the 21 car-related fatalities was known, and 19 were males. Fatalities during typhoons were significantly higher than fatalities during heavy rains ($p < 0.01$) for car-related fatalities.

Comparison of damages of recent heavy rains and typhoons in Japan

Fig. 5 shows the comparison of the damages caused by recent heavy rains and typhoons in Japan. Fig. 5A shows the correlations between the number of completely collapsed houses and fatalities after heavy rains or typhoons

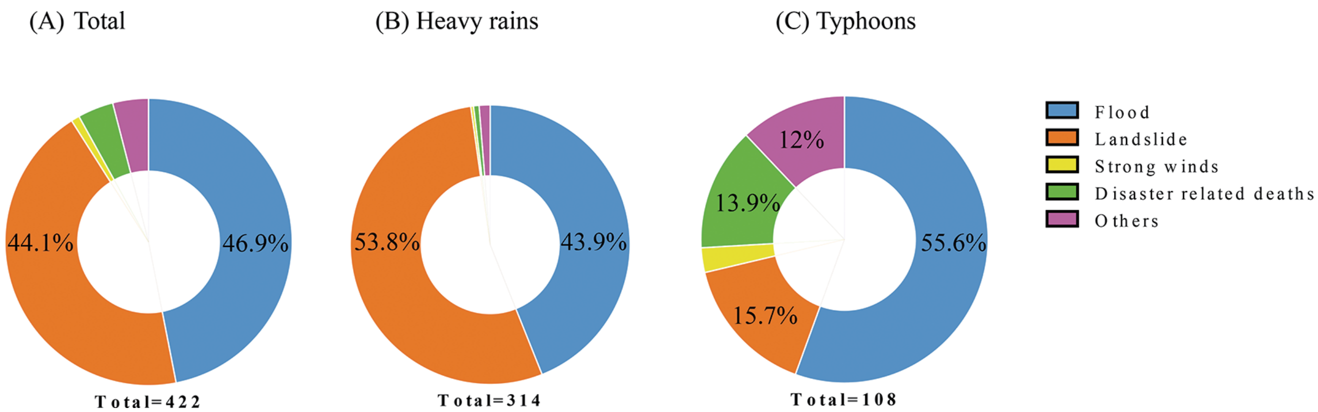

Fig. 3. Cause of fatalities in heavy rains and typhoons.
Blue: Category 1 (flood), Orange: Category 2 (landslide), Yellow: Category 3 (strong winds), Green: Category 4 (disaster related death), and Pink: Category 5 (others).

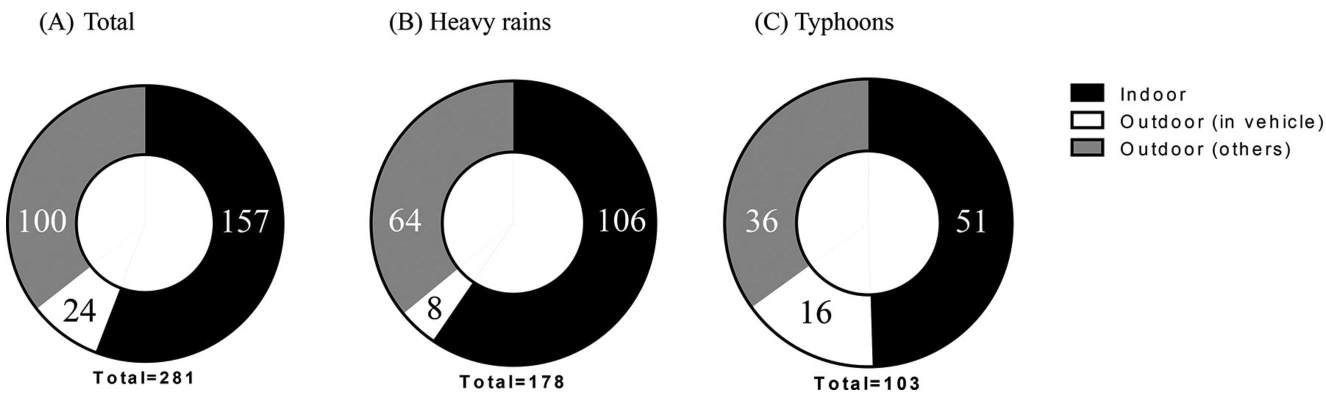

Fig. 4. Discovery location of the fatalities in heavy rains and typhoons.
Black: Indoor, White: Outdoor (in vehicle), and Gray: Outdoor (others).

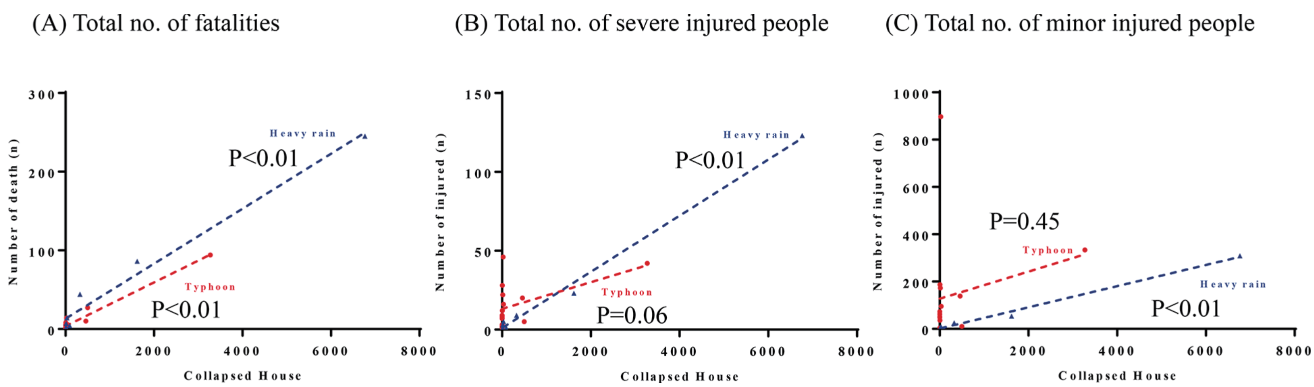

Fig. 5. Linear regressions between the total number of completely collapsed houses and personal damage related to heavy rain (blue dotted line), or typhoon (red dotted line).
(A) Equations are shown in the figure. X and Y indicate the total number of completely collapsed houses and the fatalities after heavy rains or typhoons, respectively. (B) Equations are shown in the figure. X and Y indicate the total number of completely collapsed houses and the total number of severely injured people after heavy rains or typhoons, respectively. (C) Equations are shown in the figure. X and Y indicate the total number of completely collapsed houses and the total number of minor injured people after heavy rains or typhoons, respectively.

during the 5 years. A significant correlation exists between completely collapsed houses and the number of fatalities from both hazards ($p < 0.01$). Fig. 5B shows the correlations between the number of completely collapsed houses and the number of severely injured people after heavy rains or typhoons during 5 years. Fig. 5C shows the correlations between the number of completely collapsed houses and the number of minor injured people after heavy rains or typhoons during 5 years. A significant correlation exists between completely collapsed houses and the number of people severely and minor injuries due to heavy rains ($p < 0.01$). The number of completely collapsed houses by typhoons tended to correlate with the number of severely injured people ($p = 0.06$), but not with the number of minor injured people ($p = 0.45$).

The correlation of the location of fatalities with the actual inundation area in 2020 Kumamoto Heavy Rain disaster and current hazard map.

Heavy rains killed 63 people in southern Kumamoto Prefecture in 2020. Most of the fatalities were elderly, with a median age of 80 years old (68.5-84.5). The fatalities

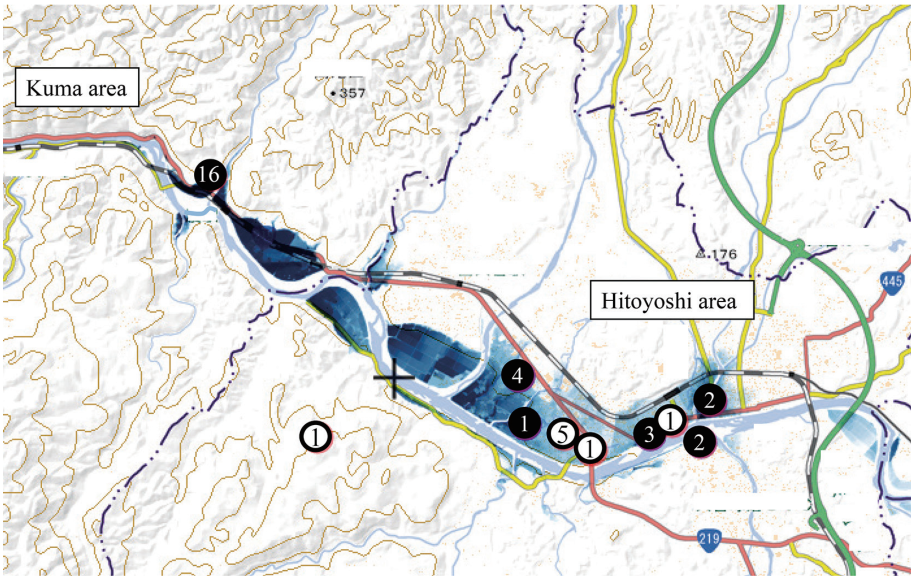

Fig. 6. Discovery place of the fatalities on actual inundated area in 2020 Kumamoto Heavy Rain; https://www.pref.kumamoto.jp/common/UploadFileOutput.ashx?c_id=3&id=37204&sub_id=1&flid=257410 [*Accessed*: November 5, 2020].
Of the 45 people, 36 who know the detailed address were mapped. Most of fatalities were in inundation estimated area. Black circle white numerals: Indoor deaths, White circle black numerals: Outdoor deaths. This version of hazard map was modified after 2020 Kumamoto Heavy Rain and the possible hazard area was extended considering the maximum inundation.

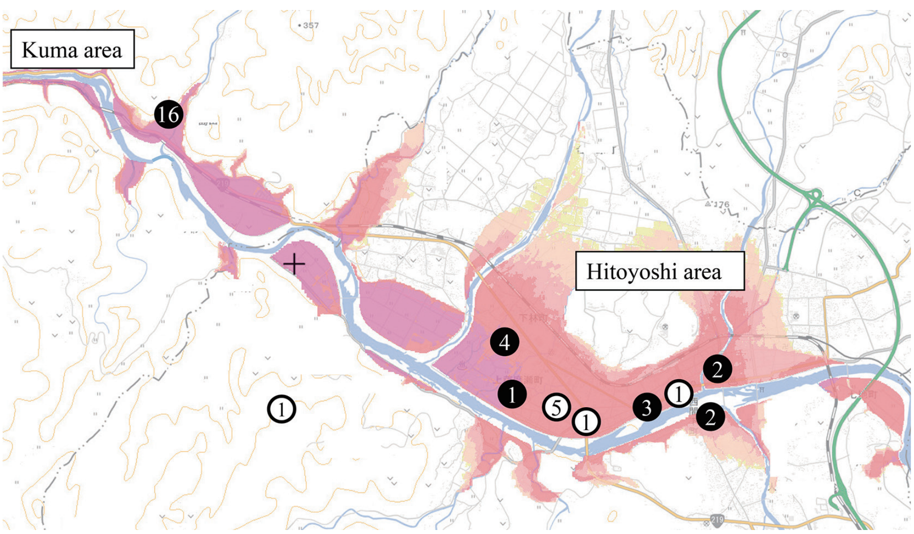

Fig. 7. Discovery location of the fatalities on pre-disaster hazard map.
Of the 45 people, 36 whose detailed addresses are known were mapped. Most of the fatalities were inundated areas on hazard maps. Black circle white numerals: Indoor deaths, White circle black numerals: Outdoor deaths. This map was revised after 2020 to widen the possible hazard area.

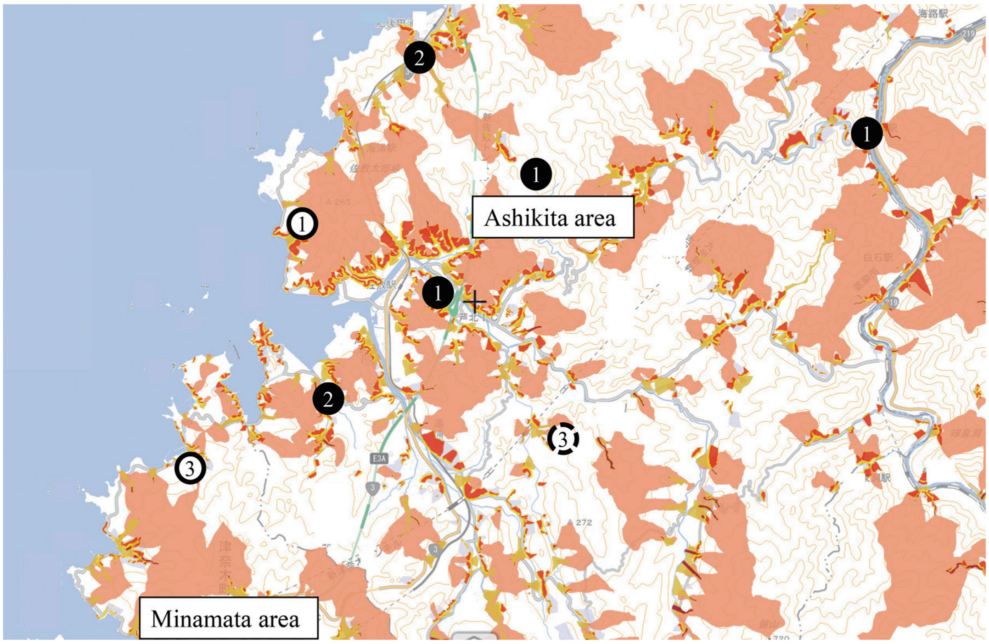

Fig. 8. Discovery location of the fatalities of heavy rain in Minamata and Ashikita area.
The figure created by the sediment disaster area map is made by the hazard map portal site. Fourteen with known detailed addresses were mapped. Most fatalities were in dangerous areas on the hazard maps. Black circle white numerals: Indoor deaths, White circle black numerals: Outdoor deaths. White circle with black dotted line shows that fatalities were killed in their house by landslides and found outdoors.

were mainly from Hitoyoshi and Kuma (45 people) or Minamata and Ashikita (14 people) areas with different causes. Of the 45 fatalities, 44 (97.8%) from Hitoyoshi and Kuma areas were caused by floods. Moreover, 12 of the 14 (85.7%) fatalities from the Minamata and Ashikita areas were caused by landslides.

Most of the fatalities are within or close to the inundated area (Fig. 6). The possible hazard area is wider than in Fig. 6 and all fatalities except one are within the possible hazard area because of the revision after 2020 (Fig. 7). All fatalities are within or close to the sediment disaster area (Fig. 8). The study indicated that the fatalities had stayed in areas marked dangerous.

Discussion

The study found that most of the fatalities had stayed in areas marked dangerous and were elderly. In addition, the number of fatalities correlated with the number of completely collapsed houses during recent heavy rains and typhoons.

Seven occurrences of heavy rains and 16 typhoons killed 578 persons in Japan between 2016 and 2020 with an average of approximately 100 fatalities per year. The characteristics of the fatalities in Japan were found to be (1) elderly people, (2) mainly caused by floods or landslides due to heavy rains, and (3) a correlation was noted between completely collapsed houses and the fatalities. Thus, it suggests that staying home when heavy rains or typhoons may cause the total collapse of the house does not assure safety to the residents.

The study found that of the 465 fatalities, 334 (73.2%) were older than 60 years old, suggesting that older people are very vulnerable to heavy rains and typhoons, while younger people had lower mortality. Young adults (10-19 years old), in their 20s, and those > 60 years old have a higher vulnerability to flooding (Ashley and Ashley 2008). This specific age vulnerability was similar to the findings reported by the current report. However, the difference is that the proportion of fatalities was much lower in young people than older people. Vulnerabilities increase with age (Myung and Jang 2011). The social background explains the result (e.g., declining birthrate and aging population). Fig. 9 shows that the population and fatalities in Hitoyoshi and Kuma area, and Ashikita and Minamata area due to 2020 heavy rain. This figure shows that the aging of the region affects the number of fatalities. Of the fatalities in the Hitoyoshi and Kuma areas, 14 (nine and five people in their 80s and 90s, respectively) expired at the nursing home. Elderly people were killed because they remained in the danger zone and they could not evacuate themselves or be evacuated with their caregivers.

The sex analysis in the current study revealed that heavy rains and typhoons had caused mortalities in more males (n = 195, 53.1%) than females (n = 172, 46.9%) in Japan. The current result is similar to previous studies (Ashley and Ashley 2008; FitzGerald et al. 2010; Doocy et al. 2013; Salvati et al. 2018). However, sex differences were not huge in Japan compared with other countries. Due to previous disaster reports, the vulnerability of females in some low-income countries was because of the sex roles of

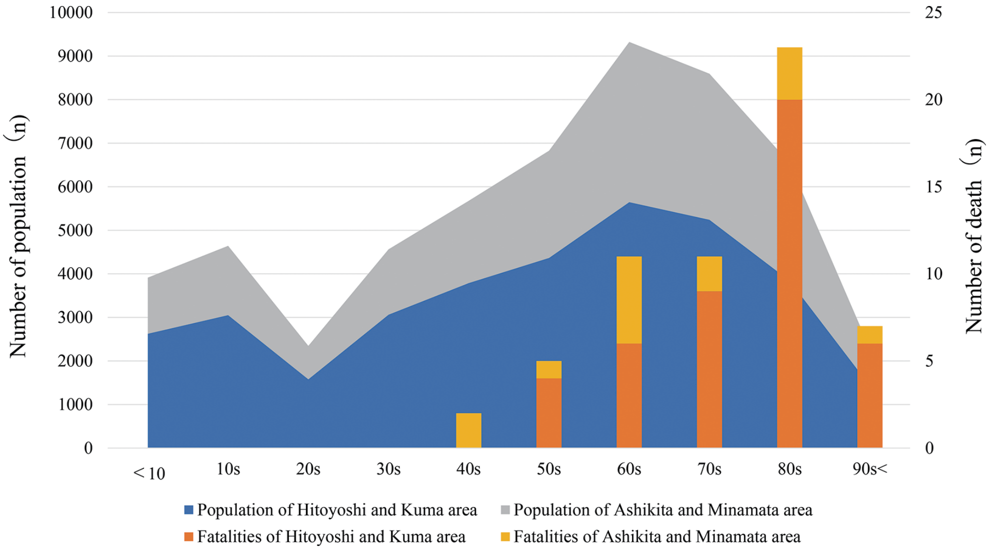

Fig. 9. Comparison of population composition and the number of fatalities
Blue: Population of Hitoyoshi and Kuma area, Gray: Population of Ashikita and Minamata area, Orange bar: Fatalities of Hitoyoshi and Kuma area, and Yellow bar: Fatalities of Ashikita and Minamata area.

society (Fothergill 1996; Doocy et al. 2013). However, Japan is a high-income country and, females take on family, society, and economic roles comparable to those of males. The social role was the reason why many males have expired (Salvati et al. 2018). Nonetheless, there was no sex difference in Japan.

Many age-related vulnerabilities and indoor sacrifices were thought to be the reason. Moreover, floods killed more females than males in people > 70 years old (Salvati et al. 2018). Fig. 4A showed that fatalities occurred more frequently indoors (n = 157, 55.9%) than outdoors (n = 124, 44.1%). Thus, indoor mortality is considered a factor that eliminates differences in social roles in high-income countries. The analysis of the current study indicated that the most vulnerable were the elderly. Therefore, this study shows the importance of providing information on safe areas, appropriate evacuation warnings, and evacuation plans for the elderly in Japan.

The current analysis showed that some of the outdoor fatalities expired from behaviors not related to evacuation behavior (i.e., going out by car, checking the situation, and falling into the river). Twenty-four fatalities were noted in connection with motor vehicles. Previous reports showed that the fatalities took a significant risk, often underestimating the depth and force of the flowing water when deciding to cross floodwaters by motor vehicles (FitzGerald et al. 2010; Diakakis and Deligiannakis 2013). Of the 21 fatalities, 19 were males. The National Police Agency in Japan reported that five times as many males (n = 42,228) compared with females (n = 8,113) have a driver's license and are > 65 years old (National Police Agency 2021). Therefore, this is influenced by the driving time and many driving opportunities of males. Sex differences also had an effect, and men were thought to more likely behave recklessly. Salvati quoted the Social Issue Research Centre report and said something similar (SIRC 2004; Salvati et al. 2018). Thus, education on dangerous behavior during flood disasters was also important. Heavy rains caused most fatalities due to landslides (53.8%) and floods (43.9%), and typhoons caused most fatalities due to floods (56.6%) and landslides (16.0%). Fig. 3B and C showed a difference in landslide mortality rates between heavy rains and typhoons. Thus, the results in Fig. 8 suggest that 10 of the 14 victims of the landslides have been discovered indoors. Moreover, one of the causes of many indoor fatalities in Japan was the influence of living in a landslide-prone area. Furthermore, this indicates that staying indoors in landslide prone areas is critically dangerous. Another factor is the strong winds that could be the cause of mortalities during typhoons. They were categorized but the percentage was as low as 9%. Only 8% of coastal typhoon fatalities in the total death toll in the USA were mainly due to strong wind (Rappaport 2014). This result is similar to the report of the current study.

The current study showed that the main causes of fatalities were floods and landslides. The analysis of flash floods in the USA concluded that the most important factors are the short event duration, small catchment size, and low night visibility (Spitalar et al. 2014). The analysis in France of flash floods found that small catchments with a response time shorter than 1 h are the most dangerous, producing large numbers of fatalities (Ruin et al. 2008). Moreover, landslides were difficult to predict (Salvati et al. 2018). This may reflect rainfall and regional characteristics. A correlation exists between the number of fatalities and the number of completely collapsed houses during heavy rains and typhoons (p < 0.01). Based on this, the number of completely collapsed houses can serve as an index of the hazard size in flood damage, and the proportional magnitude of human damage was shown. Heavy rains showed a correlation between the number of injured people and the number of completely collapsed houses ($p < 0.01$).

Typhoons tended to correlate with the number of severe injured people and the number of completely collapsed houses ($p = 0.06$). However, it did not correlate to people who are minorly injured ($p = 0.45$). Hence, the number of total collapsed houses and fatalities per year or disaster is much larger in heavy rains than in typhoons. Heavy rain causes landslides more than typhoons and fatally injure people indoors.

Falling brought about by strong winds was possibly the cause of injury due to typhoons. In addition, the national government in 2013 defines the destruction of a house as "a thing that is severely damaged and difficult to reuse by repair" in the "Disaster Damage Certification Criteria." Specifically, the house is recognized as destroyed if the economic damage is ≥ 50% of the entire house. In addition, if damage above a certain level exists due to the action of external forces (e.g., tsunami, overflow, levee breach, water flow, mudflow, rubble, and so on), the inundation depth is ≥ 1.8 m above the floor at first glance. Sometimes, the damage ratio of the dwelling house is set to ≥ 50% and is said to be destroyed (Cabinet Office 2021b). Thus, completely collapsed houses are a combination of catastrophic house destruction and inundation by floods and/or landslides. The number of fatalities and collapsed houses increases in correlation with the disaster damage severity.

The current study is consistent with the concept of disaster risk presented by Egawa et al. (2017) and Egawa (2021), and could be reflected as the results of the hazard size. A previous study also reports a correlation between the number of completely collapsed houses and the number of mortalities due to collapsed houses in inland earthquakes (Naito et al. 2020). Moreover, the total number of fatalities tends to be proportional. Thus, the hazard size is a factor in the loss of life regardless of the hazard type.

Focusing attention on the collapse of river banks and sediment-related disasters is necessary when a large amount of rain accompanies it. In the heavy rain in 2020, a riverbank collapsed about 1 h after the warning. In addition, a sediment-related disaster occurred about 7 h after the announcement of the sediment-related disaster warning (Kumamoto Prefecture 2020a, b). Many fatalities occurred in dangerous areas (Figs. 6, 7 and 8). Thus, the hazard map contributes to disaster risk reduction.

In summary, the fatalities were in proportion to the hazard size and elderly vulnerability. Improving resilience by grasping the danger area by the hazard map and disseminating correct knowledge are important to reduce these risks. In addition, an early warning system that can promptly disseminate and grasp information on danger is necessary. Local governments are obliged to make efforts on promoting the establishment of region-wide policies including individual evacuation plans (Cabinet Office 2021c). Simultaneously, educating people in Japan about dangerous behaviors in the event of strong winds and floods is necessary. Finally, this study is believed to help reduce the fatalities of disasters caused by heavy rains and typhoons.

The limitation of this study is the limited time for data collection. The data that was collected for a limited time, may affect future environmental changes, the condition of residences and houses, and so on. Moreover, future disaster damage depends on the hazard and exposure, vulnerability and coping capacity. Thus, continuous and systematic data collection of disaster damage is necessary. Another limitation of this study is the limitation of access to disaggregated data. In some documents, the details of victims (sex, age, location of discovery, and so on) are not available.

In conclusion, this study showed that the damage by heavy rains and typhoons increases the risk of disasters depending on the size of hazards and the vulnerability of the elderly. Thus, disaster risk reduction and education for the hazard risk and safe evacuation plans using hazard maps are important for strengthening disaster resilience.

Conflict of Interest

The authors declare no conflict of interest.

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Appendix

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