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Temporal Trends in Treatment Interruption among the Victims of Heavy Rain Disasters in Japan: Findings from Emergency Medical Team Data

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Abstract

Objectives: Treatment interruptions in disaster victims are concerning, owing to an increase in natural disasters and the growing elderly population with chronic conditions. This study examined the temporal trends in treatment interruptions among victims of 2 recent major heavy rain disasters in Japan: West Japan heavy rain in 2018 and Kumamoto heavy rain in 2020.
Methods: Data for this study were derived from the national standardized medical data collection system called the "Japan Surveillance in Post-Extreme Emergencies and Disasters." Joinpoint regression analysis was performed to examine the daily trends in treatment interruptions reported soon after each disaster onset.
Results: A total of 144 and 87 treatment interruption cases were observed in the heavily affected areas of the West Japan heavy rain in 2018 and Kumamoto heavy rain in 2020, respectively. In both disasters, a high number of treatment interruption cases were observed on the first day after the disaster. Joinpoint regression analysis showed that trends in the percentage of treatment interruptions differed between the 2 disasters at different disaster scales.
Conclusions: The findings suggest the importance of a prompt response to treatment interruptions in the immediate aftermath of a disaster and consideration of the specific characteristics of the disaster when planning for disaster preparedness and response.

Over the past few decades, the number of natural disasters has increased worldwide. In particular, water-related disasters, such as rainfall-induced floods, have become more frequent owing to the effects of climate change; the number of floods increased by 2.18 times globally between 1998 and 2022.[1] Water-related disasters cause a wide range of health-related problems, such as injuries, infectious diseases, deterioration of pre-existing health conditions, and psychological problems.[2] Hence, there is an urgent need to generate scientific knowledge in response to the alarming increase in such disasters.

A growing body of evidence has highlighted the challenges of treatment interruptions caused by disasters. For example, a study of 1043 Hurricane Katrina survivors aged ≥18 years found that 73.9% of the survivors had 1 or more pre-existing chronic conditions, and 20.6% of them experienced treatment interruptions because of the disaster.[3] Another study on Hurricane Katrina showed increased odds of acute symptoms among 1455 evacuees in American Red Cross shelters in Louisiana who had concurrent illnesses and lacked medication due to the disaster (odds ratio = 2.22).[4] Similarly, treatment interruption problems were observed in the Great East Japan Earthquake in 2011; an exacerbation in blood pressure and blood glucose control was reported among victims with pre-existing health conditions, such as chronic kidney disease and diabetes.[5] Given the increasing trend of natural disasters and the growing aging population with chronic diseases, the burden associated with treatment interruptions may become even greater in the future.

Although treatment interruptions owing to natural disasters have been investigated, some important issues remain unaddressed. First, most studies on this issue have been conducted weeks or months after the onset of disasters.[3–5] This may be attributed to the difficulty of data collection on health-related events in the acute phase of a disaster.[6] Thus, evidence of treatment interruptions in the immediate aftermath of a disaster is scarce. Second, to the best of our knowledge, no previous study has examined temporal trends in treatment interruptions immediately after a disaster. Such evidence is essential for response planning and interventions for treatment interruptions among disaster victims with pre-existing health conditions.

In the aftermath of natural disasters, Emergency Medical Teams (EMTs) play a crucial role in addressing heightened health care demands when the local medical capacity is overwhelmed. In Japan, after the Great East Japan Earthquake in 2011, a standardized disaster medical reporting form and system called the "Japan Surveillance in Post-Extreme Emergencies and Disasters" (J-SPEED) was developed to address the challenge of collecting and compiling disaster medical records reported by EMTs. J-SPEED has enabled the collection of real-time health-related data during past emergencies or natural disasters in Japan.[7–9] Following the J-SPEED, in 2017, the World Health Organization (WHO) developed the EMT Minimum Data Set (MDS) as an international standardized medical data collection system.

The present study examined and compared temporal trends in treatment interruptions among victims of 2 recent major heavy rain disasters in Japan using J-SPEED data collected by EMTs.

Methods

Study Setting

The present study used the J-SPEED data on 2 recent major heavy rain disasters in Japan, the 2018 Japan floods (hereinafter referred to as "West Japan heavy rain 2018") and the 2020 Kyushu floods (hereinafter referred to as "Kumamoto heavy rain 2020"). The West Japan heavy rain 2018 occurred mainly in Okayama, Hiroshima, and Ehime Prefectures between June 28 and July 8, 2018, and the Kumamoto heavy rain 2020 occurred primarily in Kumamoto Prefecture between July 3 and July 8, 2020. EMTs were dispatched to the affected areas immediately after the onset of each disaster. They used the J-SPEED form to report information on the patients they treated and sent the data to the EMT Coordination Cell during disaster response periods. The J-SPEED data were collected from July 8-September 11, 2018 for the West Japan heavy rain 2018 and July 5-July 31, 2020 for the Kumamoto heavy rain 2020. Table 1 presents details of these 2 disasters[10–20]

Table 1. General information on the 2 heavy rain disasters

	West Japan HR 2018	Kumamoto HR 2020	
	Disaster overview		
Population[a, 10–13]	6 076 181	1 737 660	
Population density, people/km^2[a, 11–14]	285.6	426.4	
Rainfall[b,15]	433.2 mm	847.5 mm	
Number of dead[c,16,17]	263	84	
Number of missing[c,16,17]	8	2	
Number of injured[c,16,17]	484	80	
	J-SPEED Data		
Affected prefectures	Hiroshima, Okayama, Ehime	Kumamoto	
EMT response days	41 days	27 days	
Number of EMTs deployed	85	80	
Number of daily reports	402	208	
Number of patient consultations	3620	816	
Number of treatment interruptions	150	101	
	Disaster situation in affected city/town with high treatment interruption in the J-SPEED		
Affected city/town	Kurashiki City, Okayama	Hitoyoshi City, Kumamoto	Ashikita Town, Kumamoto
Flooded areas	1200 ha[18]	70 ha[d, 19]	—
Number of damaged buildings	4600[18]	130[d, 19]	1870[20]
Number of victims	—	1277[d,20]	2612[20]
Number of patient consultations in J-SPEED	2104	473	242
Number of treatment interruptions in J-SPEED			
All ages	144	53	34
0–14 years old	1	3	3
15–64 years old	60	7	7
≥65 years old	83	43	24

Abbreviations: ha, hectare; HR, Heavy Rain; J-SPEED, Japan-Surveillance in Post-Extreme Emergencies and Disasters.
[a]Total population of Hiroshima, Okayama, and Ehime Prefectures in 2018 for the West Japan HR 2018; Population of Kumamoto Prefecture in 2020 for the Kumamoto HR 2020.
[b]Rainfall average of Hiroshima City (Hiroshima Prefecture), Okayama City (Okayama Prefecture), and Matsuyama City (Ehime Prefecture) for the West Japan HR 2018; Rainfall of Kumamoto City (Kumamoto Prefecture) for the Kumamoto HR 2020.
[c]Data from the Japan Meteorological Agency and the Fire and Disaster Management Agency reports.
[d]Data on the most affected region in Kuma Village, Kumamoto Prefecture.

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Study Design

This study focused on treatment interruptions in the most heavily affected regions, as the number of treatment interruptions in Kurashiki City, Okayama Prefecture accounted for 96% of the total number of treatment interruptions in the J-SPEED data for the Kumamoto heavy rain 2020. Furthermore, the number of treatment interruptions in Hitoyoshi City and Ashikita Town, Kumamoto Prefecture, accounted for 86% of the total number of treatment interruptions in the J-SPEED data for the West Japan heavy rain 2018.

Treatment Interruption

In J-SPEED, treatment interruption is defined as the interruption of necessary treatment owing to a disaster. It has been reported that disasters interrupt treatment such as medication use in patients with pre-existing health conditions.

Data Analysis

First, treatment interruptions based on demographic information were analyzed to examine the overall picture of events during the EMT response for each disaster. Spearman's rank correlation was calculated to assess the correlation between the total number of consultations, including all health-related consultations and the number of treatment interruptions.

Joinpoint regression analysis was used to examine the temporal trends in the percentage of treatment interruptions. To perform this analysis, a 3-day moving average was calculated for the percentage of treatment interruptions among the total number consultations for data smoothing and visualizing the overall trends of treatment interruptions. The proportion was calculated as the 3-day moving average of treatment interruption divided by the total number of consultations.

The joinpoint regression model enabled the identification of joinpoints that revealed a significant shift in the trends of treatment interruptions and estimated the daily percentage rate change (DPC) between these joinpoints. Details of the mathematical explanation of the DPC can be found in previous reports.[21,22]

Data analyses were performed using Microsoft Excel (Microsoft Corp., Redmond, Washington, USA), EZR Software (Saitama Medical Center, Jichi Medical University, Saitama, Japan), and Joinpoint Trend Analysis Software (version 5.0; National Cancer Institute, Maryland, USA).

Results

Table 1 presents the general information on the 2 heavy rain disasters. Compared to the Kumamoto heavy rain 2020, the population of the affected area of the West Japan heavy rain 2018 was approximately 3.5 times larger, and the number of deaths, missing people, and injuries was 3-6 times higher. According to the J-SPEED data, 85 and 80 EMTs were deployed in the affected regions of the West Japan heavy rain 2018 and Kumamoto heavy rain 2020, respectively. Among the 3620 and 816 consultations in the West Japan heavy rain 2018 and Kumamoto heavy rain 2020, 150 (4.1%) and 101 (12.4%) experienced treatment interruptions, respectively. These treatment interruptions were mainly observed in Kurashiki City, Okayama Prefecture ($n = 144$), in the West Japan heavy rain 2018 and in Hitoyoshi City and Ashikita Town, Kumamoto Prefecture ($n = 87$), in the Kumamoto heavy rain 2020. The number of patients registered in J-SPEED was 4.4 times higher in the West Japan heavy rain 2018 than in the Kumamoto heavy rain 2020, whereas the difference was relatively small for the number of treatment interruptions, approximately 1.5 times higher.

Figure 1A depicts the daily reported number of treatment interruptions in Kurashiki City, Okayama Prefecture, during the

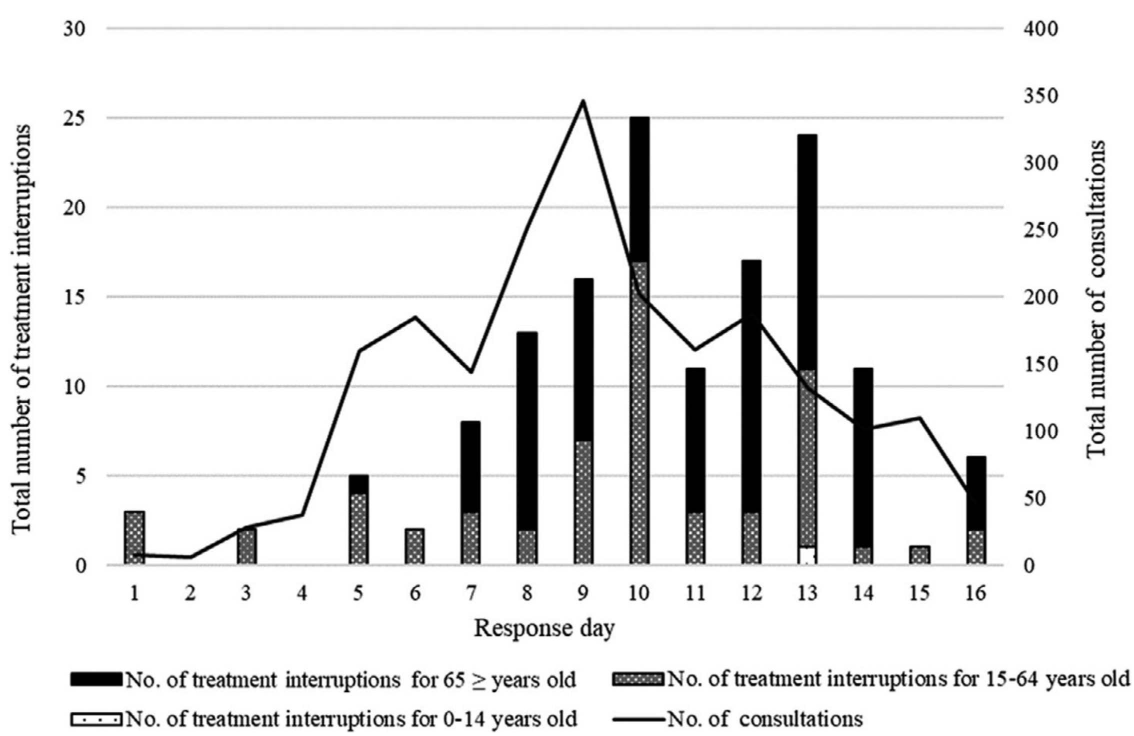

Figure 1A. Daily reported number of treatment interruptions in Kurashiki City, Okayama Prefecture during West Japan heavy rain 2018.

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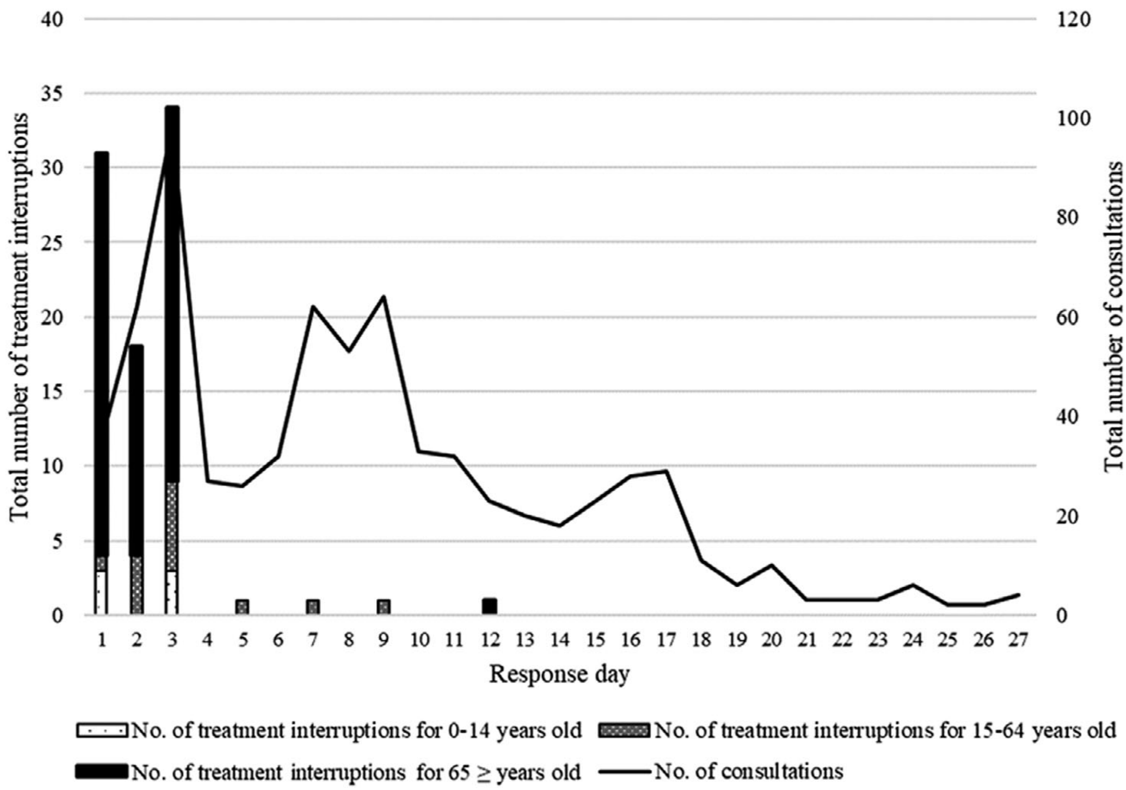

Figure 1B. Daily reported number of treatment interruptions in Hitoyoshi City and Ashikita Town, Kumamoto Prefecture during Kumamoto heavy rain 2020.

EMT response to the West Japan heavy rain 2018. The number of treatment interruptions gradually increased until day 10, reached a maximum of 25, and then decreased thereafter. The total number of consultations showed a similar trend, increasing until day 9 and then decreasing thereafter. The Spearman's rank correlation coefficient between the total number of consultations and the number of treatment interruptions was 0.694 ($P = 0.003$).

Figure 1B illustrates the daily reported number of treatment interruptions in Hitoyoshi City and Ashikita Town, Kumamoto Prefecture, in response to the Kumamoto heavy rain 2020. The number of treatment interruptions was relatively high in the first 3 days and reached a maximum of 34 on day 3. Thereafter, the numbers decreased and maintained a decreasing trend. The total number of consultations reached a maximum of 98 on day 3. The Spearman's rank correlation coefficient between these numbers was 0.610 ($P < 0.001$).

Figure 2A shows the results of the joinpoint regression analysis examining the daily trends in the percentage of treatment interruptions during the EMT response to the West Japan heavy rain 2018 in Kurashiki City, Okayama Prefecture. Three distinct change points in the trend were analyzed over the 14 days of reported treatment interruptions. The proportion of treatment interruptions was 11.9% on day 1, which significantly decreased from day 1 to day 3 (DPC = –53.59% from day 1 to 3, $P < 0.05$), subsequently increased until day 12 (DPC = 25.63% from day 3 to 12, $P < 0.05$), and then decreased (DPC = 27.88% from day 12 to 14, $P < 0.05$).

Figure 2B shows the daily trends in the percentage of treatment interruptions during the EMT response to the Kumamoto heavy rain 2020 in Hitoyoshi City and Ashikita Town, Kumamoto Prefecture. Two distinct change points were identified in the trend during the 12-day study period. The proportion of treatment interruptions was 42.6% on day 1, decreased from days 1 to 6 (DPC = -59.36% from day 1 to 6, $P < 0.05$), and then remained constant.

Discussion

During the EMT response period, 144 and 87 cases of treatment interruptions were reported in the most affected regions of the West Japan heavy rain 2018 and Kumamoto heavy rain 2020, respectively. The present study found a significant correlation between the total number of consultations and the number of treatment interruptions in both disasters, whereas the peak in the number of treatment interruptions was different for each disaster. A high percentage of treatment interruptions was observed in the first few days of the EMT response period for both disasters, whereas the subsequent trend in treatment interruptions differed between the 2 disasters.

A relatively high percentage of treatment interruptions were observed soon after the onset of both heavy rain disasters. This observation may be attributed to the immediate need for treatment and the increased awareness of individuals' vulnerability in the aftermath of such disasters. This urgency may have been exacerbated by inadequate preparedness for disasters, such as the lack or loss of medication stockpiles, prescription records, and health insurance cards, or failure to bring such items during evacuation.[23] A systematic review of 29 studies on medication loss and treatment interruptions in past disasters highlighted that inadequate stockpiling of medicines often leads to treatment interruptions.[24] This suggests that the lack of preparedness, particularly among individuals with chronic conditions, may have contributed to the high rate

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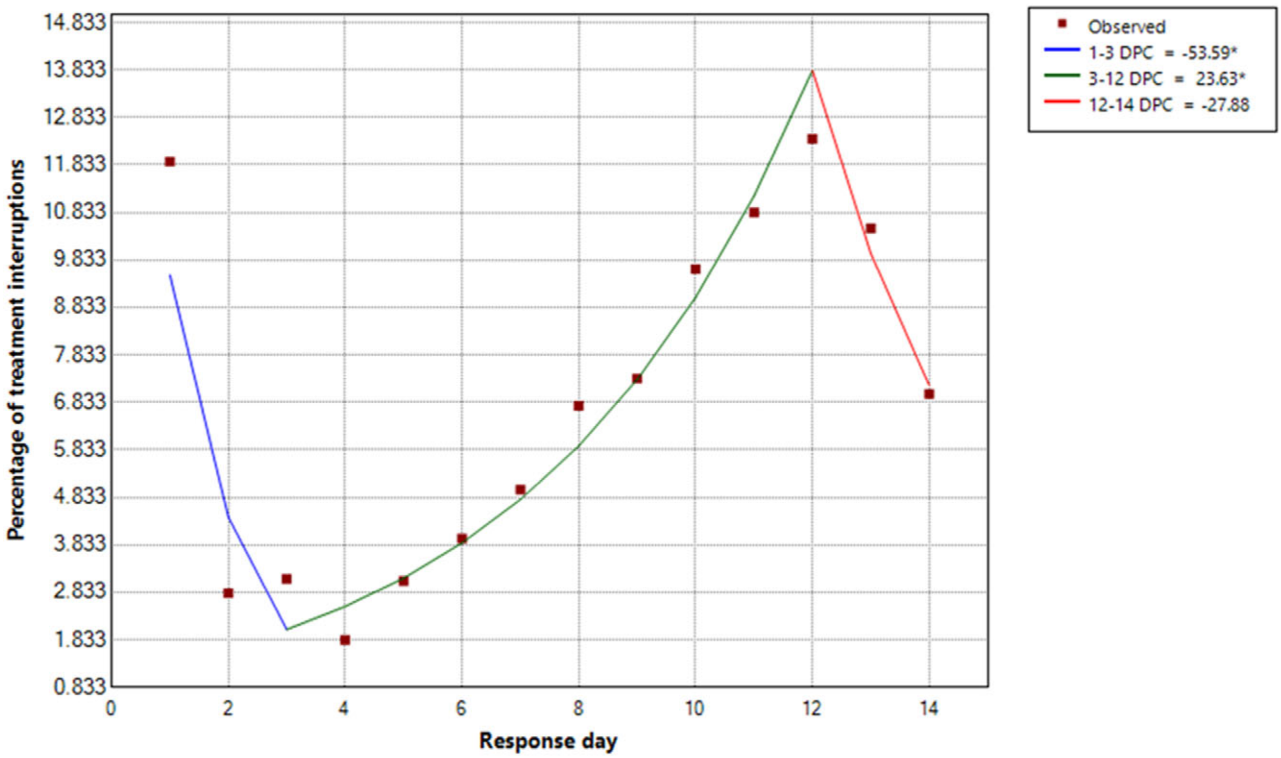

Figure 2A. Daily trend in the percentage of treatment interruptions in Kurashiki City, Okayama Prefecture during West Japan heavy rain 2018.

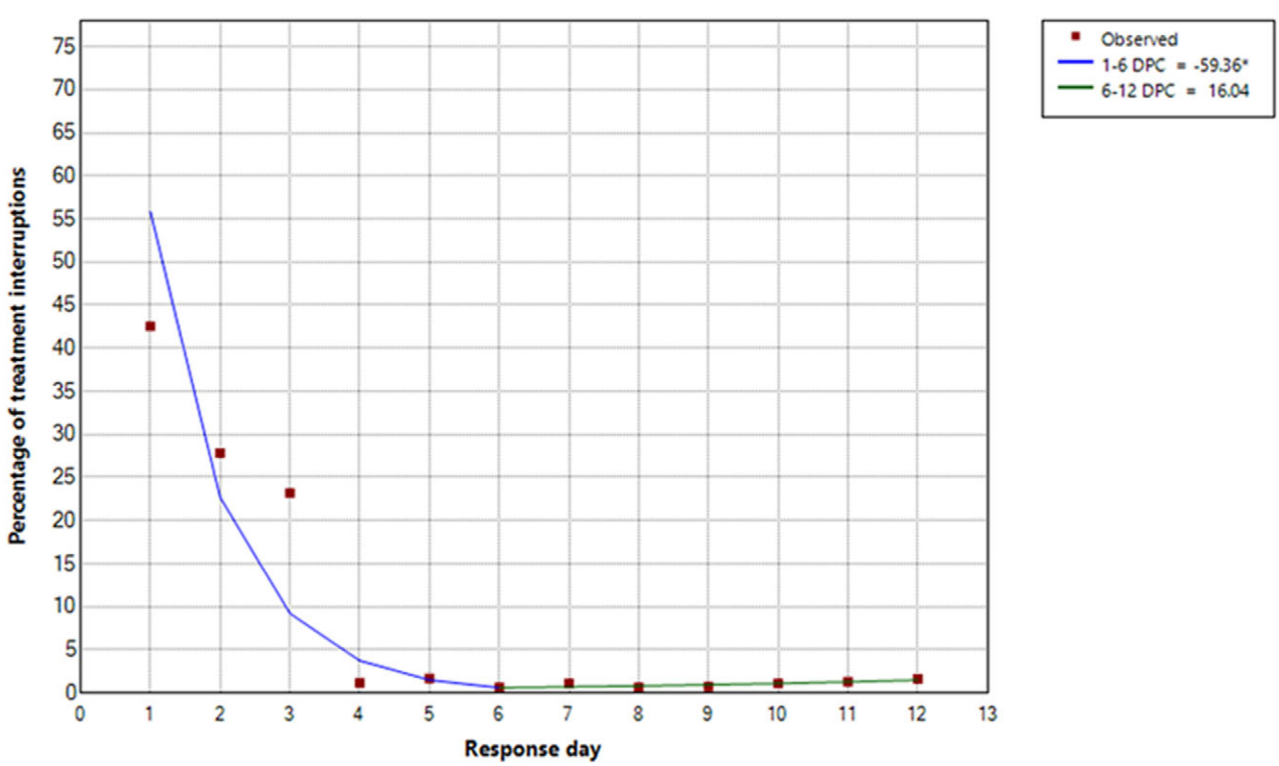

Figure 2B. Daily trend in the percentage of treatment interruptions in Hitoyoshi City and Ashikita Town, Kumamoto Prefecture during Kumamoto heavy rain 2020.
*indicates that Daily Percentage Change (DPC) is significantly different from zero at p-value<0.05.

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of treatment interruptions immediately after the disasters. While stockpiling medications is generally recommended, certain medications and conditions present challenges for long-term storage.[24] Therefore, preparedness strategies, including stockpiling, should be personalized based on individual circumstances, such as the type of medication and its shelf life, to effectively mitigate the risk of treatment interruptions in future disasters. In addition, during the Great East Japan Earthquake, many survivors lost their regular medications because of damage to their homes due to flooding.[25] Additionally, the flooding may have contributed to the loss of medication for the people under treatment, leading to treatment interruptions. Another possible explanation for the observed trend during initial days of the disaster is that sudden damage, such as power failure, may have caused treatment interruptions. In the Great East Japan Earthquake, 4.2% of patients with lung or heart disease exhausted the oxygen cylinders, which were used in home therapy of patients with hypoxemia, due to power outage.[26] The present study added evidence of treatment interruptions in the immediate aftermath of a heavy rain disaster, using real-time daily reports from EMTs via the J-SPEED.

The present study revealed that the subsequent trend of treatment interruptions differed for each heavy rain disaster, with the percentage of treatment interruptions increasing in the mid-phase of disaster response only in Kurashiki City, Okayama Prefecture in the West Japan heavy rain 2018, which may be attributed to differences in the scale of the disasters. This increase may be more pronounced in the West Japan heavy rain 2018 than in the Kumamoto heavy rain 2020 because of the larger scale of the disaster in terms of flooded areas, number of damaged buildings, and number of victims. Larger-scale disasters may extend the EMT response period, resulting in a gradual shortage of prepared medical supplies during the later response phase. As for the prolonged evacuation period, it is possible that victims who were able to take medications from their homes ran out of them.[27] For example, in the Noto Peninsula Earthquake in 2007, 84% of those who evacuated with regular medicines for chronic diseases ran out of stockpiles at the end of the evacuation period.[27] Similarly, during Hurricane Ivan in Florida in 2004, 10% of the affected households reported problems in obtaining medicines 1 week after the disaster due to the lack of money, fuel, and transportation.[28] In addition, as the response phase progressed, EMTs may have become more proactive in providing medical consultations regarding treatment interruptions, which is reflected in the increase in cases. Moreover, during the Great East Japan Earthquake, the large-scale of the disaster prolonged the length of evacuation period. This resulted in a large gap between the medical supplies prepared by EMTs and those needed by the evacuees and a shortage of medications.[24] On the other hand, it should be noted that the proportion of treatment interruptions was higher in the Kumamoto heavy rain 2020 compared with the West Japan heavy rain 2018 despite the smaller scale. This may be attributed to the demographic characteristics of the affected population, particularly the higher proportion of older patients aged ≥ 65 years in the Kumamoto heavy rain 2020 (approximately 63% in the Kumamoto heavy rain 2020 vs. 37% in the West Japan heavy rain 2018). This comparison underscores the importance of tailoring disaster-response strategies to both the scale of the disaster and the specific needs of the affected population.

During the Kumamoto heavy rain 2020, the percentage of treatment interruptions continued to decrease throughout the EMT response period in the 2 most affected regions. In the Kumamoto heavy rain 2020, which caused smaller-scale damage than that caused by the West Japan heavy rain 2018, EMTs may have identified the medication needs of the victims more quickly and supplied them with medications. This may have resulted in the gradual decrease in treatment interruptions during the response period. In addition, in the case of the Kumamoto heavy rain 2020, mobile pharmacy (i.e., a vehicle with pharmacy functions that can independently dispense and supply medicines in the affected areas) was deployed to Hitoyoshi City 4 days after the disaster.[29] Furthermore, the deployment of mobile pharmacy may have contributed to the continuous decrease in treatment interruptions. Similarly, during Hurricane Sandy in 2012, the use of mobile health units deployed by the North Shore-Long Island Jewish Health System played a critical role in the effectiveness and workflow of the operation by continuing to identify and provide feedback on the medical and other needs of the affected population during medical activities in the early stages of response. Furthermore, the timing of the mobile pharmacy deployment was a day different between the Kumamoto heavy rain 2020 and West Japan heavy rain 2018; the mobile pharmacy was dispatched 5 days after the evacuation shelter was opened in the Kumamoto heavy rain 2020,[29,30] and 6 days after the West Japan heavy rain 2018.[31] This slight difference in the timing of mobile pharmacy deployment may have contributed to the different trends in treatment interruptions between these heavy rain disasters.

Our findings have several implications for future research. The relatively high proportion of treatment interruptions during the first few days of the 2 heavy rain disasters indicated the need to strengthen disaster response activities for victims who may experience treatment interruptions caused by disasters. Additionally, this observation highlights the importance of deploying resources such as pharmacists and mobile pharmacies immediately after a disaster to address diverse medication needs. Mobile pharmacies were introduced in Japan following the Great East Japan Earthquake in 2011. Subsequently, the number of mobile pharmacies have increased with increasing demand. Given the increasing number of disasters and the growing elderly population living with chronic conditions, enhanced reach of mobile pharmacies should be considered in future disasters. The different temporal transition in treatment interruptions in the latter phases of the 2 disasters suggest that disaster-related characteristics may underlie these trends. This finding is important for implementing interventions based on disaster-related characteristics and may contribute to reducing the burden associated with treatment interruptions in future disasters. In addition, this study examined temporal trends in treatment interruptions using data from the treatment interruption item included in the J-SPEED form. However, the WHO MDS form, the international version of J-SPEED, does not include a section on treatment interruptions. To further understand the challenges of treatment interruptions in different settings and strengthen the global surveillance system, consideration should be given to the inclusion of such an item in the MDS.

Limitations

The present study has several limitations. First, individual-level patient data on treatment interruptions were limited and not used; instead, aggregated data from daily reports of patient consultations were used to examine the trends in treatment interruptions. Thus, utilizing individual-level data may provide a better understanding of the treatment interruptions caused by disasters. Second, the timing of data collection differed slightly between the 2 disasters, which may be attributed to a gap in the experience of EMTs using J-SPEED between 2018 and 2020. Furthermore, this difference may have led to a potential underestimation of treatment interruptions in the first few days following the West Japan heavy rain 2018. Third, data collected by EMTs were analyzed using J-SPEED; thus, data on disaster victims who had access to local medical facilities were not considered. However, disaster victims treated by EMTs may represent a more vulnerable patient group than those with access to medical facilities. Fourth, the scarcity of cases within certain age categories limits the capacity to draw comprehensive conclusions specific to each age cohort; thus, our findings may not be generalizable to distinct age groups.

Conclusions

During the EMT response period in the West Japan heavy rain 2018 and Kumamoto heavy rain 2020, the percentage of disaster victims who experienced treatment interruptions was higher in the first few days. Furthermore, the patterns of the subsequent trends varied based on the characteristics of each disaster. These findings suggest the importance of responding to treatment interruptions in the immediate aftermath of a disaster and considering disaster-related characteristics, such as the disaster scale and timing of mobile pharmacy deployment, in disaster response planning and health care frameworks, which may reduce the increasing burden of treatment interruptions.

Author contribution. Yuichi Nakamura and Ami Fukunaga were co-senior authors.

YN and AF drafted the manuscript. YN conducted data analysis. AF confirmed the analysis and edited the manuscript. KA, YT, KC, SM, AW, HK, and YK contributed to the data collection. TK provided overall supervision including project management and conceptualization of research. All authors reviewed and approved the final version of the manuscript.

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Competing interest. None to declare.

Ethical standard. The J-SPEED study was approved by Hiroshima University (Hiroshima, Japan) Ethics Committee (approval number: E-2059).

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