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The impact of COVID-19 on heat-related ambulance calls and the challenges for emergency medical transport in the Kansai region, Japan: a mixed methods approach

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Abstract

The COVID-19 pandemic, coupled with more frequent and stronger heatwaves, has introduced a novel confluence of challenges. In Japan, emergency medical transport staffs are facing increasing difficulty in distinguishing between COVID-19 and heat stroke at the scene because they share some similar symptoms. This study explored the impacts of the COVID-19 pandemic on heat-related ambulance calls and identifies the challenges faced by local fire departments in the Kansai region of Japan over 2020–2022. Both historical data analysis and an online questionnaire survey were used in this study. We utilized a heat-related ambulance calls prediction model developed in our previous research based on the historical data (2008–2019) to project the expected number of heat-related ambulance calls from 2020 to 2022. Subsequently, we compared expected number and the actual number of daily heat-related ambulance calls to examine the variations of heat-related ambulance calls across six prefectures in the Kansai region. Our findings reveal a significant decrease in the number of heat-related ambulance calls during the COVID-19 pandemic across all Kansai prefectures, ranging from 3.2% to 22.9%. The decline in heat-related ambulance calls can be attributed to shifts in daily routines, such as the increase of remote work and decrease of outdoor exercise. However, it may also be influenced by the strain on the emergency medical resource. Furthermore, this study has also highlighted substantial pressures on local fire departments and emergency medical transport systems during the pandemic. A primary challenge for local fire departments was securing available medical facilities for patients. Improving the efficiency of the emergency medical transport system and enhancing the coordination between emergency medical services and healthcare facilities may offer a more resilient response in future crises.

1. Introduction

Humanity's failure to stop climate change has resulted in increasing emissions and higher average temperatures. Our world is already an average of 1 °C warmer than in the pre-industrial era (Allen *et al* 2018). Several regions have experienced a warmer climate by over 2 °C, while other regions have experienced relatively little change (Masson-Delmotte *et al* 2018). However, even small changes in average temperatures can result in huge changes in the intensity and frequency of extreme weather (Mearns *et al* 1984). The analysis of long-term climate records shows evidence of an increasing trend in both the frequency and the duration of extreme temperature events (Fischer and Schär 2010). Several extreme temperature events happened in the 21st century and caused massive deaths in different regions. In 2003, a record-breaking heat

wave hit many European countries and caused nearly 70 000 deaths (Robine *et al* 2008). Seven years later, another deadly heat wave occurred in Russia, where over 55 000 heat-related deaths were recorded by the Center for Research on the Epidemiology of Disasters (CRED 2010).

Heat-related health problems have also raised concerns in Japan. According to reports from the Japanese Fire and Disaster Management Agency (FDMA), 95 137 patients in 2018 and 71 029 patients in 2022 were transported by emergency ambulance services because of heat-related health problems (FDMA 2023a). Previous studies indicated that elderly people (over 65 years old) with pre-existing chronic diseases, such as cardiovascular disease (Rowell *et al* 1983) or respiratory disease (Ayres *et al* 2009) are considered to be more vulnerable to extreme heat conditions. In the past five years, more than 50% of ambulance calls due to heat stroke were from elderly people aged over 65 years old (FDMA 2023a). The combination of a super-aging society and a warming climate requires from the Japanese public to raise its awareness of heat-related health problems and take proper countermeasures in advance.

The novel coronavirus disease 2019 (COVID-19) was first reported in December 2019 (Shi *et al* 2020), and spread globally at an unprecedented speed. COVID-19 has resulted in over 6.76 billion infections around the world (as of 10 March 2023) (Johns Hopkins University 2023) and 33.8 million in Japan (as of 8 May 2023) (NHK 2023). Japan has experienced eight waves of COVID-19 infections since 2020. The seventh wave of COVID-19 infections that started in late June and peaked in August 2022 was the most extensive outbreak Japan had encountered, resulting in over 1.47 million diagnosed COVID-19 cases and over 290 000 individuals hospitalized (NHK coronavirus data 2023). In response, the Japanese Ministry of Health, Labor and Welfare (MHLW 2020a) issued guidelines, advising individuals to prevent the infection of COVID-19 by avoiding the so-called '3 Cs', e.g. closed spaces with poor ventilation, crowded places with many people nearby, and close-contact settings such as close-range conversations. The release of public health recommendations led to changes in people's lifestyles in Japan including the increase in remote work (Morikawa 2022) and the reduction of outdoor exercise (MILT 2020). It was reported that 49.6% of the total number of companies in Japan adopted remote work systems in early 2020 (Morikawa 2022). Additionally, an online survey conducted in August 2020 indicated a 13.8% increase in the daily time spent indoors and 18.8% reduction in outdoor activities during the pandemic period in Japan compared to the pre-pandemic era (MILT 2020).

Changes in people's lifestyles caused by COVID-19 and the warming climate resulted in a new problem: actions that have been applied to prevent COVID-19 infections may have increased the risks of heat-related health problems (MHLW 2020b). For example, to prevent the spread of COVID-19, individuals were encouraged to ventilate rooms frequently. However, room ventilation under high outdoor temperatures may increase indoor temperatures, and therefore increase the risk of heat strokes (Kanda *et al* 2023). Other protective actions, such as mask-wearing (especially for protective face masks) and social isolation for elderly people, were also considered to be risk factors related to heat-related health problems (Kanda *et al* 2023). High numbers of heatstroke patients and COVID-19 patients in summertime during the COVID-19 pandemic put extremely high burdens on the ambulance call system.

Differentiating heat-related health problems and COVID-19 has also been challenging for emergency transport since they share the same major clinical symptoms, such as high fever, headache, nausea, general fatigue, and consciousness disorder (Kanda *et al* 2023), while no specific biomarkers exist to diagnose them (Nakahara *et al* 2021). Polymerase Chain Reaction test and the history of close contact with confirmed COVID-19 patients could support diagnosis at the scene of emergency transport, but they cannot completely remove the suspicion of a COVID-19 infection (Ferretti *et al* 2020). Emergency medical technicians need to make decisions on the spot to choose an appropriate hospital for their patients. Since the COVID-19 suspected patients require isolation rooms, patients who only have a heatstroke may still be refused by the hospital unless the suspicion of a COVID-19 infection is completely ruled out. This dilemma resulted in a large number of difficult-to-transfer cases in the summers during the COVID-19 pandemic (FDMA 2024).

Several studies have investigated the effects of the COVID-19 pandemic on the heat-related ambulance calls in Japan. However, the findings among researchers remain inconsistent. Hatakeyama *et al* (2021) found that there was a statistically significant decrease in heat-related ambulance calls during the COVID-19 pandemic in most of prefectures of Japan, which may be explained by the COVID-19 precautionary actions including the 'stay-at-home' request. Uryu *et al* (2021) investigated the daily number of heat-related ambulance calls from 2008 to 2020 and found that the number of heat-related ambulance calls did not significantly change compared to the past trend. Otani *et al* (2021) examined the heat-related emergency transport data from Tottori prefecture and observed an increased risk of heat stroke in older people due to the COVID-19 countermeasures. Seposo *et al* (2021) found an overall reduction in heat-related ambulance calls, and the possible reasons were physical interventions and behavioral changes.

While the above studies provide some valuable insights, they predominantly focus on the COVID-19's initial year which is 2020. Subsequent waves of the pandemic in 2021 and 2022, which recorded significantly

higher infection rates (the fifth wave (2021/7/1–2021/9/30) and the seventh wave (2022/7/1–2022/9/30) of the COVID-19 pandemic had 202 262 and 1479 005 newly confirmed COVID-19 infections (NHK coronavirus data 2023)), present a different set of challenges. Notably, no research has yet investigated the repercussions of these later waves on heat-related ambulance calls, especially the enormous strain they placed on the emergency medical transport system. This research gap is particularly salient as understanding these impacts can be significant for future public health strategies and emergency medical transport response preparations in the face of similar crises in the future.

Thus, we conducted this research to evaluate the changes of heat-related ambulance calls during the COVID-19 pandemic. We utilized a heat-related ambulance calls prediction model to estimate the expected number of summer heat-related ambulance calls from 2020 to 2022 based on the historical data (from 2008 to 2019). A comparison was conducted between the expected number and the actual number of daily heat-related ambulance calls to check the pattern changes in all prefectures of the Kansai region. Furthermore, to have a better understanding of the challenges that emergency medical transport staffs faced during the COVID-19 pandemic, we conducted an online survey of local fire departments. The questionnaire focuses on the facts and the challenges that local fire departments faced during the seventh wave of COVID-19 pandemic (2022/7/1 - 2022/9/30), as well as about the possible solutions. We believe our research can help local fire departments and policymakers to understand the facts and challenges of heat-related emergency medical transport in the summers during the COVID-19 pandemic and to consider the actions that could be applied for the emergency medical transport system to prepare for similar pandemics in the future.

2. Method

The wet-bulb globe temperature (WBGT) is a worldwide heat index to estimate the co-effects of temperature, relative humidity, wind speed, and solar radiation. WBGT was first developed to estimate heat exposure in the marine military, where humidity was of concern for soldiers in military training clothes and subject to a significant risk of heat stress (Yaglou and Minard 1957). In this research, we chose WBGT rather than air temperature to evaluate heat stress since Japan experiences both high temperatures and high humidity in summer. Observed WBGT data have only been provided at limited weather stations since 2006 in Japan. Therefore, we used the estimation method proposed by Ono and Tonouchi (2014), which can estimate WBGT with a bias of less than 1.0 °C with 98.3%–99.8% confidence (equation (1)). Meteorological data from 2008 to 2022, including air temperature, relative humidity, solar radiation, and wind speed, were obtained from Japan Meteorological Agency (JMA 2023),

$$\begin{aligned} WBGT = {} & 0.735 \times Ta + 0.0374 \times RH + 0.00292 \times Ta \times RH + 7.619 \times SR - 4.557 \\ & \times SR^2 - 0.0572 \times WS - 4.064 \end{aligned} \tag{1}$$

where Ta is standard air temperature (°C), RH is relative humidity (%), SR is daily solar radiation (kW m2), and WS is wind speed (m s^{-1}).

We selected six prefectures in the Kansai region: Shiga, Kyoto, Osaka, Nara, Hyogo, and Wakayama, as our research areas. We also used data from weather stations that are located near major urban areas to represent the weather conditions in each prefecture. As some weather stations had missing values for some days, we used data from the nearest weather station in place of the missing values. Daily heat-related ambulance call data were collected from Japan's Fire and Disaster Management Agency (FDMA 2023b). We chose the period 2008–2022 for historical analysis because Japan's FDMA has collected and provided heat-related ambulance call data since 2008.

According to Japan's FDMA, heat-related ambulance call refers to the situation where people are transported to medical institutions by ambulance and are diagnosed with heat stroke after initial examination. Heat stroke here is defined as "a general term for disorders that occur when the body's water and salt (sodium, etc) imbalance occurs due to a breakdown in the body's ability to regulate the heat in a hot environment. It includes sunstroke, heat cramps, heat exhaustion, and heatstroke (FDMA 2023b). FDMA's data include different levels of heat-related health impacts, ranging from mild (i.e. does not require hospitalization) to severe (requires hospitalization of 3 weeks and more). Death is also included in this dataset. Daily new confirmed COVID-19 cases data were obtained from MHLW (2023). The data include the daily number of new confirmed COVID-19 cases in 47 prefectures of Japan from 2020/1/16–2023/5/8.

We employed a heat-related ambulance call prediction model to assess the impacts of COVID-19 on heat-related ambulance calls during the pandemic. The model is designed to predict daily heat-related ambulance calls over a wide range of regions by introducing heatwave features such as accumulated heat stress, heat acclimatization, and optimal temperature. Accumulated heat stress is used to calculate heat stress

accurately when hot days persist over an extended period. Epidemiological studies in different countries have demonstrated that the heat-related health impacts are typically delayed by 2 or 3 d (Saez *et al* 1995, Hajat *et al* 2002, Honda *et al* 2014), while the lag effect plays a significant role in the proper assessment of accumulated heat stress. Heat acclimatization is the beneficial physiological adaptive response to a hot environment that helps people reduce the risks of serious heat illness (Kinney *et al* 2008). It is used in our model to capture the situation that where people struggle to adapt to sudden temperature increases, even though absolute temperature not very high. Previous studies have confirmed a V-shaped relationship between temperature and the mortality rate (Honda *et al* 2014). Optimal temperature in our model is used to specify the local conditions among regions. Some demographic and socio-economic features that have been proved to be related to heat-related health impacts (McGregor *et al* 2015) are also included in our model to improve the prediction performance among regions. More details of this model can be found in our previous research (Ke *et al* 2023).

We used extreme gradient boosting (XGBoost) to develop the heat-related ambulance call prediction model. XGBoost is a scalable, distributed gradient-boosted decision tree ML library (Chen and Guestrin 2016). We employed a normalization method to preprocess the dataset, as the scales ranged from 1 to 10 000 000, causing instability in the learning process. The dataset was divided into training and testing sets in a ratio of 8–2. Then, we used randomized search cross validation with repeated 10-fold cross-validation to find the optimal hyperparameters of the XGBoost model. Finally, the adjusted coefficient of determination (adjusted R^2) and root mean squared error (RMSE) were utilized to examine model performance. Generally, a smaller RMSE value indicates better performance, whereas a higher adjusted R^2 value indicates better performance. The whole training process was conducted under Python (version 3.7.6).

To predict the number of daily heat-related ambulance calls without COVID-19's effects from 2020 to 2022, a prediction model was trained by using data from the pre-pandemic period (2008–2019). This regional-level prediction model was trained for the Kansai region, Japan, with the test RMSE 0.0106 and test adjusted R^2 0.9860. Then, we used this model together with meteorological data during the pandemic period (2020–2022) to predict the daily summer heat-related ambulance calls without the influence of COVID-19. The results of the prediction model were used to make a comparison with the actual number of daily heat-related ambulance calls reported by FDMA. The number of daily newly confirmed COVID-19 cases was also used to analyze the effects of COVID-19 pandemic on heat-related health risks.

In addition, we conducted an online survey in the Kansai region from 1 March to 15 April 2023, by using a questionnaire to investigate the real situation of heat-related ambulance calls under the 7th wave of the COVID-19 pandemic in Japan. As most Japanese local fire departments do not make public their contact information for each division, we initially described our research and requested cooperation through the inquiry forms on the local fire departments' websites. In Japan, the division responsible for emergency medical services is generally referred to as the Keibo Division, or the Kyukyu Division. To accommodate different information security policies among the local fire departments, we provided two formats of the online questionnaire for the staff responsible for emergency medical transport: one in Excel format and the another in a Google form. We collected the replies to the online questionnaire from both platforms and analyzed the data using Excel. The full version of the online questionnaire can be found in the supplemental material.

The questionnaire focused on the problems and challenges encountered by emergency medical transport service staff during the seventh wave of COVID-19 pandemic For example, whether they experienced a labor shortage or whether their requests were refused by hospitals due to suspected COVID-19 infections of their patients. The questions were designed to be easy to answer for three reasons. Firstly, there were no publicly available data for each fire department to compare pre-COVID-19 and COVID-19 pandemic situations. Secondly, regional comparisons were challenging due to variations in the size and responsibilities of each fire department's jurisdiction. Lastly, considering the busy schedules of local fire department staff, we aimed to minimize the time required to complete the questionnaire.

3. Results

3.1. Historical data analysis

We analyzed the number of heat-related ambulance calls during the COVID-19 pandemic period (2020–2022). Figure 1 indicates the overall changes of heat-related ambulance calls in each prefecture during the COVID-19 pandemic. The details number of heat-related ambulance calls and new confirmed COVID-19 cases can be found in table 1. Although the summer wave of the COVID-19 pandemic is typically considered to last from July 1st to September 30th, considering the effects of early heatwaves and heat acclimatization, we also included June in our calculations. The changes rate means how the total number of summer heat-related ambulance calls changed during COVID-19 period. For example, a 'change rate of

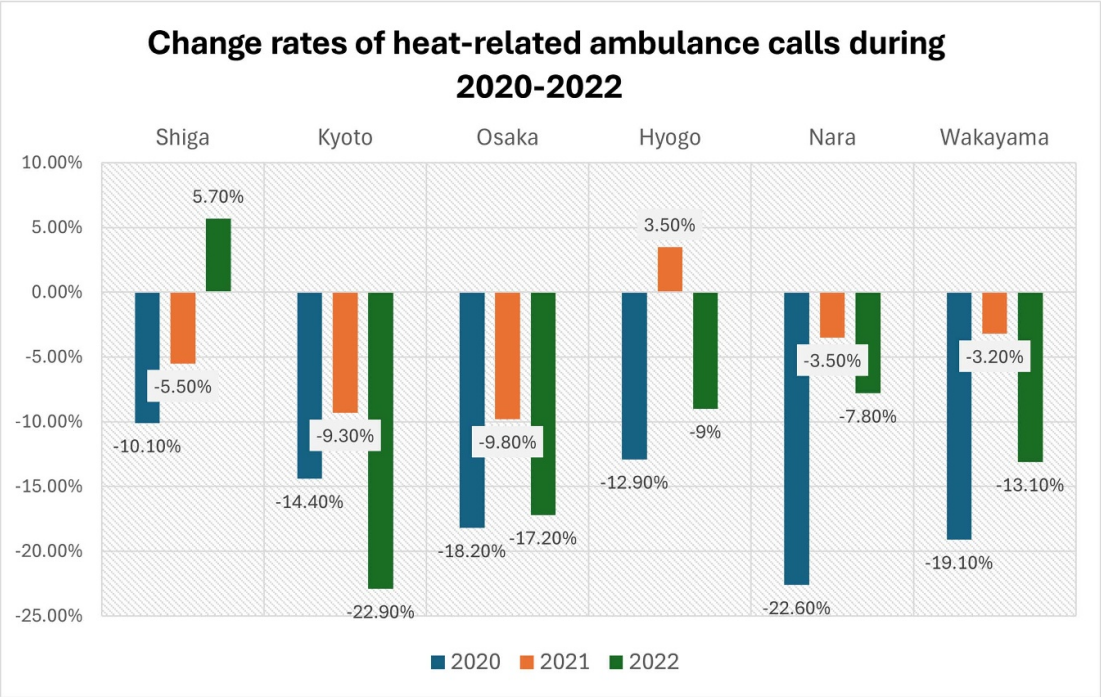

Figure 1. Change rates of heat-related ambulance calls during 2020–2022 in Kansai, Japan.

Table 1. Changes of heat-related ambulance calls (HAC) In 6 Kansai prefectures during COVID-19 Pandemic, Japan (from 2020 to 2022).

	Average daily summer WBGT	Predicted total summer HAC	Observed Total Summer HAC	Change Rate	Total number of new confirmed COVID-19
			2020		
Shiga	24.51	723	650	−10.1%	405
Kyoto	24.68	1762	1509	−14.4%	1407
Osaka	25.03	5952	4869	−18.2%	8844
Hyogo	24.96	3491	3039	−12.9%	2021
Nara	24.5	1089	843	−22.6%	479
Wakayama	25.08	820	663	−19.1%	179
			2021		
Shiga	24.04	489	462	−5.5%	7157
Kyoto	24.21	1128	1023	−9.3%	19 590
Osaka	24.49	3082	2781	−9.8%	99 681
Hyogo	24.53	1964	2033	+3.5%	37 606
Nara	23.98	599	578	−3.5%	7595
Wakayama	24.6	467	452	−3.2%	2700
			2022		
Shiga	24.83	736	778	+5.7%	142 928
Kyoto	25.05	2171	1674	−22.9%	274 192
Osaka	25.35	5387	4459	−17.2%	1121 297
Hyogo	25.4	3497	3184	−9%	583 006
Nara	24.87	1047	965	−7.8%	129 845
Wakayama	25.5	826	718	−3.1%	90 852

−5%' means that according from historical data, a certain type of weather condition resulted in a total of *N* people being transported by emergency services because of heat-related health problems. However, due to the impact of COVID-19, the actual number of people transported by emergency services decreased to 95% *

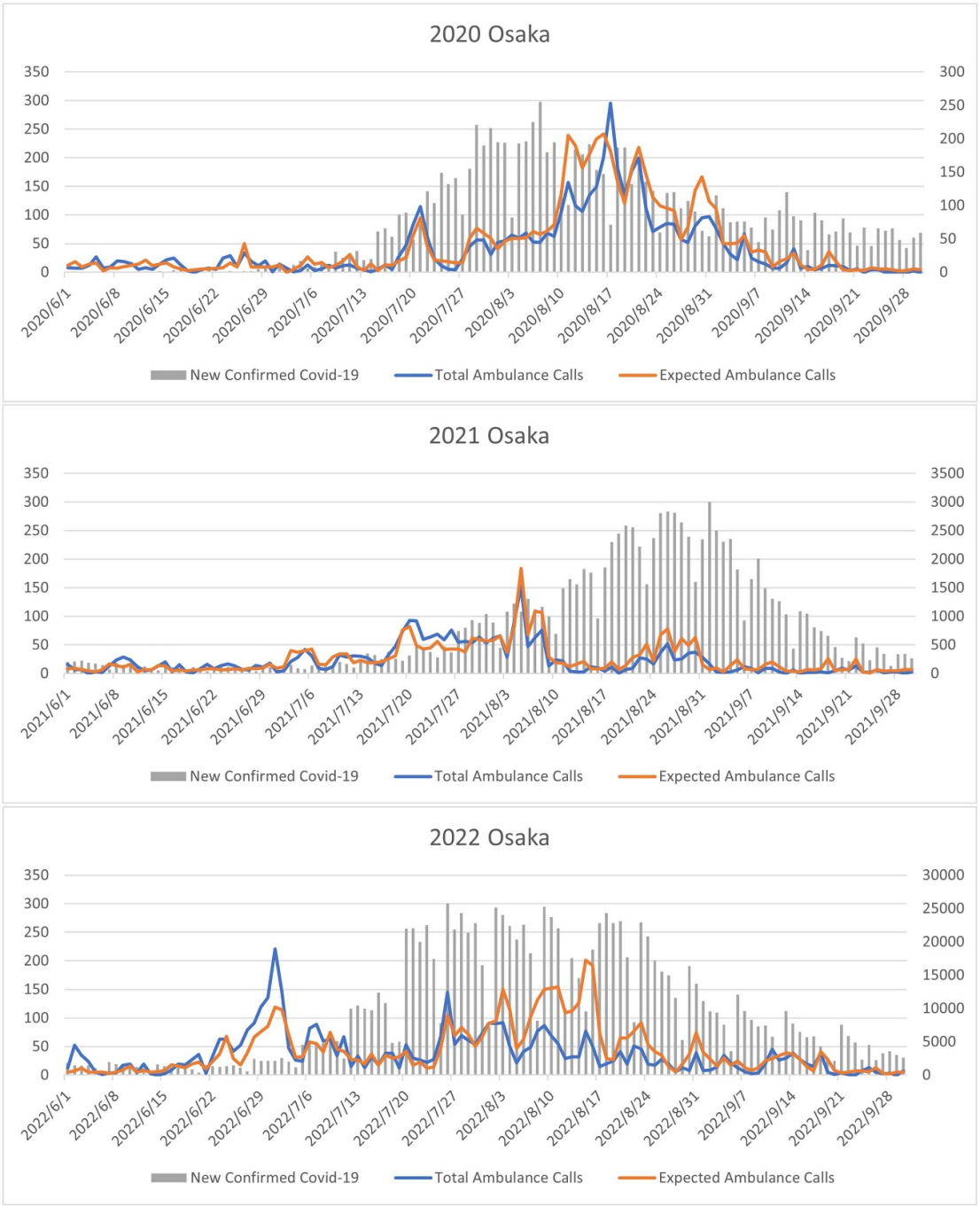

Figure 2. The trends of daily heat-related ambulance calls and the newly confirmed COVID −19 cases in Osaka. The blue lines represent the observed values of total heat-related ambulance calls, while the orange lines indicate the predicted values of total heat-related ambulance calls. The gray histogram displays the number of daily newly confirmed COVID −19 cases. The left *y*-axis represents the number of daily heat-related ambulance calls, while the right *y*-axis represents the number of daily newly confirmed COVID-19 cases.

N. Compared to the pre-COVID-19 period (2008–2019), a statistically significant overall decrease, ranging from 3.2% to 22.9%, was observed in the number of heat-related ambulance calls in most regions, except Hyogo Prefecture in 2021 and Shiga Prefecture in 2022. We found that despite a significantly higher total number of COVID-19 infections during the summers of 2022 and 2021 compared to 2020, the number of heat-related ambulance calls decreased. The biggest decrease occurred in 2020, while the decrease in heat-related ambulance calls was relatively smaller in 2021.

Figure 2 shows the trends of daily heat-related ambulance calls and the newly confirmed COVID-19 cases in Osaka. The trends of daily heat-related ambulance calls and the newly confirmed COVID-19 cases in the other 5 Kansai prefectures can be found in the supplementary material. We found a significant decrease of

heat-related ambulance calls in all prefectures in 2020 and in the summer of 2022. In these two years, the decrease of heat-related ambulance calls happened in spite of the large increase of new COVID-19 cases. In these six prefectures, the pattern of change in the number of heat-related ambulance calls remains consistent. Our results showed that the decrease in the number of heat-related ambulance calls mainly occurred at the end of July and August. It was particularly evident especially in 2020 and 2022 August. The reduction in the number of heat-related ambulance calls coincided with the periods of rapid increase in new COVID-19 cases. At the same time, our results also indicated that the number of heat-related ambulance calls was even higher than expected number during early summer (from the end of June to July). These periods were concentrated in the early summer and occurred when there were few new COVID-19 cases.

3.2. Results of the online questionnaire survey

We conducted an online questionnaire survey to assess the occurrence of heat-related ambulance calls during the 7th wave of the COVID-19 pandemic (summer 2022) in Japan. We contacted 75 local fire departments in the Kansai area to seek their cooperation for our survey. Among them, 38 fire departments responded positively and expressed their willingness to support our research. Ultimately, we received 33 valid responses to our questionnaire (figures 3 and 4).

According to the questionnaire's results, 85% (28 out of 33) of the local fire departments experienced a labor shortage during the seventh wave of the COVID-19 pandemic (Q1). Most respondents (31 out of 33, or 94%) reported difficulties in finding medical facilities to receive their patients (Q2). Almost half of them (14 out of 33, or 42%) increased their temporary emergency transport teams to meet the demand during the 7th wave (Q3). During the COVID-19 pandemic, 75% (25 out of 33) of the emergency medical transport teams observed an increase in the average response time at the scene (from the time of ambulance arrival to the time of departure for the hospital) within 10 min, while 9% (3 out of 33) reported an average response time exceeding 10 min (Q4). The main reason for the delay reported in the responses to Q4 is that most fire departments (27 out of 33, or 82%) found that they needed to contact medical facilities more often to find an available space to receive their patients than in the pre-pandemic period (Q5). Almost all of the emergency medical teams (32 out of 33, or 97%) stated that they experienced situations where the medical facilities refused to accept their patients due to suspicions of COVID-19 infection (Q6). 82% (27 out of 33) of the fire departments found it difficult to distinguish heatstroke symptoms from COVID-19 symptoms at the scene of emergency transport, due to the simultaneous occurrence fever, headache, fatigue, etc. in both heatstroke and COVID-19 patients (Q7). Over 85% (28 out of 33) of fire departments believed that the biggest challenge they faced during the pandemic is finding medical facilities that can accept their patients (even if the patient was not infected with COVID-19) (Q8).

4. Discussion

Our results indicate that a statistically significant overall decrease can be observed in the number of heat-related ambulance calls in most Kansai regions in 2020–2022. The reasons for this decrease are complex. One possible reason is the changes in individual behavior because of the government's declarations of a state of emergency or non-binding self-restrictions due to local government requests (Hatakeyama *et al* 2021, Otani *et al* 2021, Uryu *et al* 2021). However, we cannot find any declarations by the government of a state of emergency in the summers of 2020 and 2022 in these regions. The only declaration of a state of emergency was in the summer of 2021. For example, Osaka experienced a state of emergency from August 2nd to September 30th (Osaka Prefecture Government 2021). Despite the moderate summer temperatures during this period, there was still a noticeable continuous decline in daily heat-related ambulances calls in Osaka.

Although the timing of emergency declarations during other periods may not be consistent with the reduction in heat-related ambulance calls, our results also indicated behavioral changes, including stay-at-home requests, cancellation of outdoor activities, and implementation of remote work, have had some impacts on the decrease of emergency transports, which is consistent with previous studies (Hatakeyama *et al* 2021, Otani *et al* 2021, Uryu *et al* 2021). The implementation of stay-at-home requests and the restrictions on outdoor activities can lead to a decrease in overall exposure to high temperatures, which are major risk factors for heat-related illnesses. By staying indoors and avoiding outdoor strenuous activities, individuals may have reduced their chances of experiencing heatstroke and the need for emergency medical transport. Additionally, the shift towards remote work arrangements could have contributed to a decrease in heat-related emergencies as individuals could have more control over their working environment, allowing them to adapt to their surroundings to prevent overheating and dehydration. Although the exact relationship between these behavioral changes and the decrease in heat-related ambulance calls may vary across regions and individuals, it is plausible to consider that changes in individual behavior have played a significant role in reducing the risk of heat-related illness.

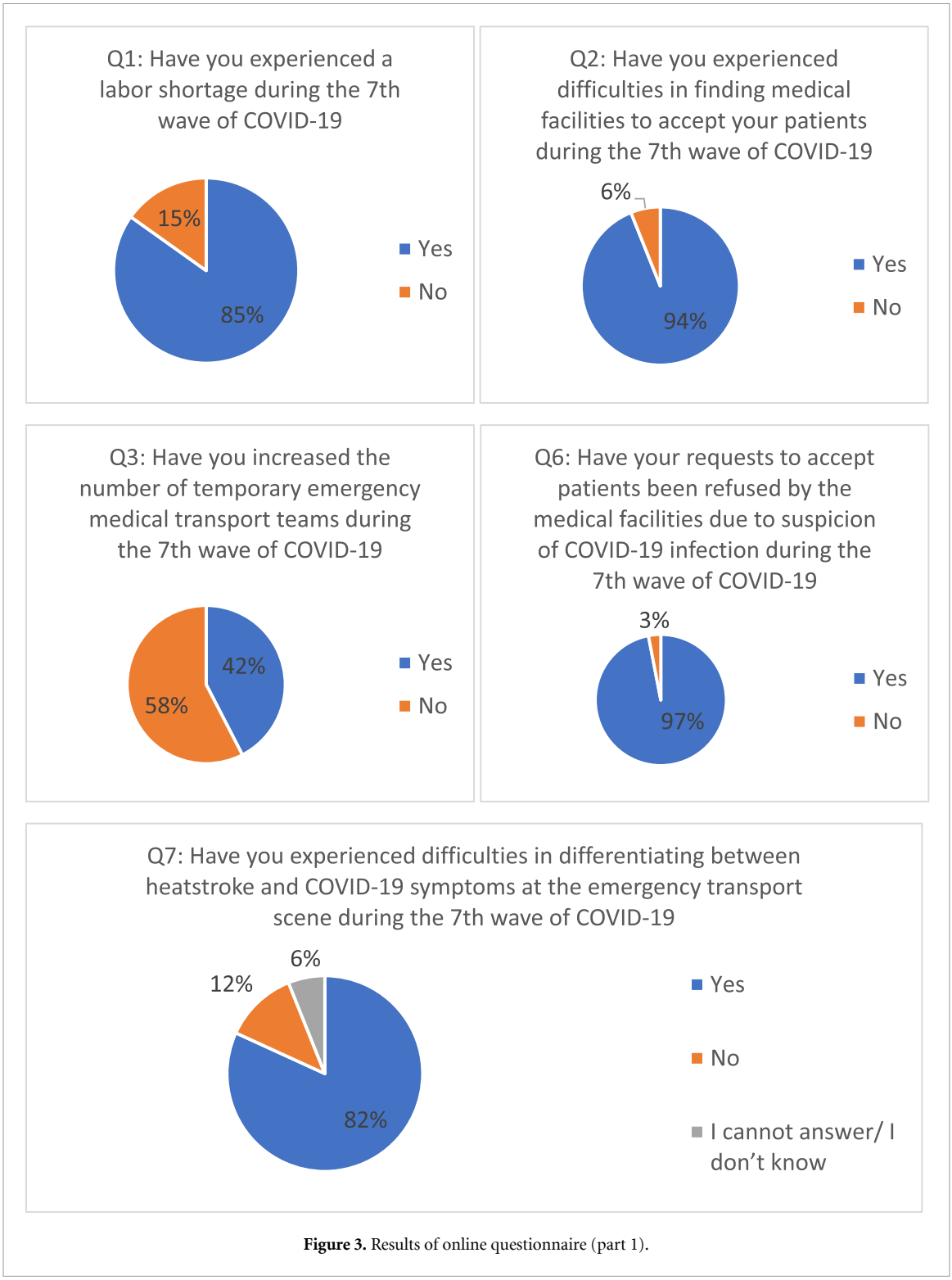

Figure 3. Results of online questionnaire (part 1).

Another possible reason for the reduction in heat-related ambulance calls could be the limited access to medical facilities or to emergency medical services due to subjective or objective factors. For example, individuals may hesitate to visit a hospital or call an emergency transport service due to concerns about potential exposure to the COVID-19 virus, or due to the desire to minimize contact with potential virus carriers during the pandemic. Individuals with mild symptoms may choose to receive at-home medical care, rather than emergency medical transport services. A survey conducted in the US indicated that 41% of the respondents opted to forgo medical service during the early stage of the pandemic (Anderson *et al* 2021). A report from another online survey also found that 12% of the respondents opted to delay or have avoided emergency medical transport services during early stage the pandemic (Czeisler *et al* 2020).

Objective factors could include disruptions or limitations of healthcare services during the COVID-19 pandemic. Hospitals and medical facilities in Japan have experienced resource constraints or diverted their

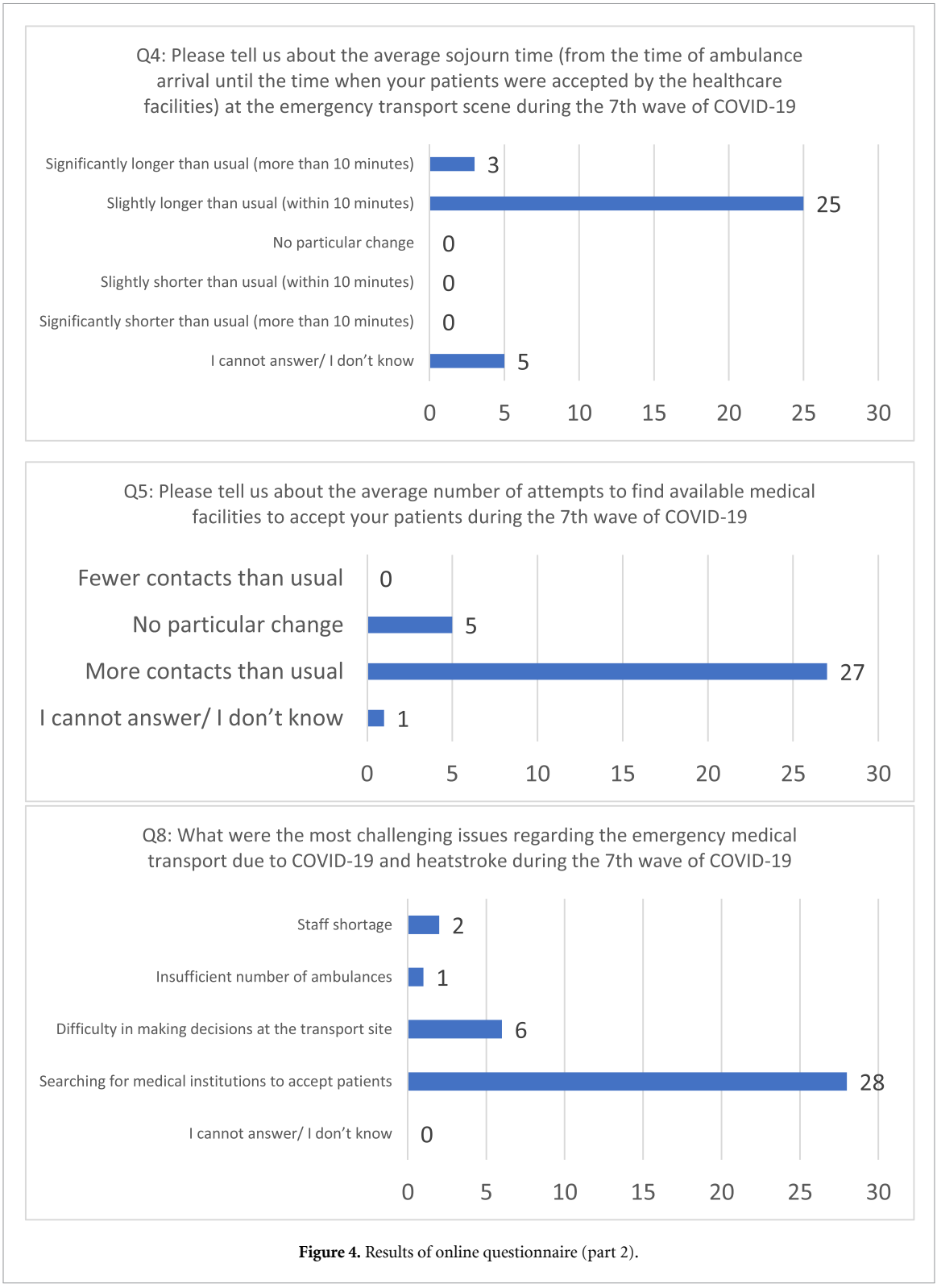

Figure 4. Results of online questionnaire (part 2).

resources towards COVID-19 responses, which could have impacted the possible usage of emergency medical transport services for heat-related cases. The results of our online questionnaire survey can also substantiate this viewpoint. Results (Q1, Q2) show 85% of local fire departments experienced a labor shortage, and 94% of respondents reported difficulties in finding medical facilities to receive their patients. The need for more time for each patient (Q3), coupled with a large number of COVID-19 patients, suggests that the emergency medical transport system may have reached a limit. This could further decrease the number of heat-related ambulance call cases. The situation where medical facilities refuse to accept their patients due to suspicion of COVID-19 infections (Q6) and the difficulty to distinguish heatstroke from COVID-19 at the scene (Q7), may also lead to the final number of heat-related ambulance calls being lower than expected. However, this

does not necessarily mean that fewer people have been affected by heat-related health problems. Unfortunately, we lack the data to confirm this.

Another common phenomenon observed in all prefectures is the increased number of heat-related ambulance calls in early summer, notably in late July 2021 and late June to early July 2022. Coincidentally, these periods preceded the next wave of COVID-19 infections. Changes in lifestyle, such as limited opportunities to go outside, may have caused some individuals to struggle with adapting to hot outdoor environments (Ioannou *et al* 2021). Special groups, especially the elderly and children, who are more sensitive to temperature changes (Perera 2008), may be at an increased risk of heat-related illness due to their limited chance to go outside and adapt well to hot outdoor environments.

Local fire departments and emergency medical transport systems have faced significant work pressure during the pandemic. During the outbreak of the pandemic, it is impossible to address the shortage of qualified emergency specialist by simply increasing their numbers. Improving the efficiency of each ambulance transport and reducing the burden of existing tasks may be a viable solution. According to the results, emergency ambulance transport staff faced challenges such as difficulty in finding hospitals willing to accept fever patients and the struggle to differentiate medical conditions based on symptoms alone. However, it is difficult to address the latter issue and ensure that similar pandemics in the future with a high mortality rate will have the same challenges. However, efforts can be made to improve the overall emergency response system and enhance coordination between emergency medical services and healthcare facilities. This can involve implementing efficient communication channels, sharing real-time patient information, and developing protocols for prioritizing and transferring patients to appropriate medical facilities. Additionally, investing in advanced information and communications technology (ICT) technologies and artificial intelligence (AI) tools for rapid diagnosis and decision-making can help improve the ability to assess patients' conditions accurately, even during challenging circumstances. Outside of Japan, many AI-related technologies have already been used to support the dispatch of ambulances. For example, AI-based triage systems have been implemented to assist emergency medical personnel in making critical decisions in Montreal, Canada (CTW news 2022). The Seattle Fire Department has utilized AI-powered dispatch systems to improve response times and optimize resource allocation (Seattle Fire Department 2019).

There are several limitations of our study. First, although we calculated the changes in heat-related ambulance calls in the pre-pandemic and the COVID-19 pandemic periods, due to many known and unknown factors affecting the usage of emergency medical transport system, we lack sufficient data to analyze the specific impact of each factor on the number of heat-related ambulance calls. Secondly, our results and conclusions are based on the changes in the number of heat-related ambulance calls. Unfortunately, we lack solid evidence to verify whether heat-related health impacts have really decreased due to various COVID-19-related factors or if it seems so due to an excessive emergency medical resource burden. Finally, our analysis was restricted to changes in emergency medical transport data in the Kansai region, and our questionnaire survey was also limited to local fire departments. In the future, we would like to conduct data analysis and related online surveys nationwide in Japan to reach more reliable conclusions.

5. Conclusion

Our study utilized a heat-related ambulance calls prediction model to estimate the expected number of heat-related ambulance calls from 2020 to 2022 based on the pre–pandemic historical data (from 2008 to 2019). A comparison was conducted between the expected number and actual daily heat-related ambulance calls recorded by FDMA to investigate the changes in heat-related ambulance calls in six prefectures of the Kansai region, Japan. Simultaneously, to gain a better understanding of the facts and challenges that the local fire departments faced during the COVID-19 pandemic, we conducted an online survey about the emergency medical transport. Our results revealed a statistically significant decrease, ranging from 3.2% to 22.9%, in heat-related ambulance calls during the COVID-19 pandemic across all Kansai prefectures. Our results indicated that the local fire departments and emergency medical transport systems encountered a significantly higher work pressure during the pandemic. The most significant challenge for the local fire departments during the COVID-19 pandemic was securing available medical facilities for their patients.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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