Impact of Temperature in Summer on Emergency Transportation for Heat-Related Diseases in Japan

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Abstract

Background: In Japan, the demand for emergency transportation for people with heat-related illness has recently increased. The purpose of this study was to investigate the relationship between incidents of heat-related illness and the daily maximum temperature.
Methods: The daily maximum temperatures in Japan's 11 districts over the past 10 years were classified into four categories, with cutoff points at the 50th, 75th, 95th, and higher than 95th percentiles. We then conducted a logistic regression analysis of emergency transportation demand in each temperature category by age group, using the 50th percentile as the reference category for each area.
Results: There were 42,931 cases of emergency transportation due to heat-related diseases during the study period. Classified by age, 12.5%, 43.4%, and 44.1% of cases involved children, adults, and elderly people, respectively. The analysis showed that the number of cases of emergency transportation for people with heat-related diseases (per 100,000 people; corresponding to a 1.0°C increase in the daily maximum temperature) was 0.016–0.106 among children (24.9–169.9 children required emergency transportation for heat-related diseases), from 0.013 to 0.059 among adults (19.8–98.2 adults required emergency transportation), and from 0.045 to 0.159 among elderly persons (30.0–145.4 elderly people required emergency transportation). The risk was highest for elderly persons, followed by children and finally adults. Cases of emergency transportation due to heat-related illness increased by 2.4–8.9 times when the daily maximum temperature was approximately 1.5°C above the mean daily maximum temperature. In fact, the daily maximum temperature had a larger effect than the daily relative humidity level on emergency transportation for people with heat-related diseases.
Conclusion: Public health organizations and health-care services should support elderly people and children, two high-risk groups for heat-related diseases.

Key words: Emergency Transportation; Heat-Related Diseases; Temperature

Introduction

There have been reports of the health impact of abnormal temperatures caused by global warming and climate variation. Existing research includes studies of the relationship between heat waves and death[1-3] and between heat and diseases[4-7] in various parts of the world. These studies have identified a recent increase in the number of patients being treated in hospitals for heat-related symptoms. For example, in Japan, heat-related diseases occur frequently between June and September. Since 2010, more than 300,000 patients have visited hospitals annually because of heat-related diseases.[8] Every summer, approximately 40,000 people call ambulances to request emergency transportation to hospitals due to heat-related illness.[9]

Heat-related indices have been developed including the Wet Bulb Globe Temperature Index (WBGT)[10] and the Universal Thermal Climate Index (UTCI).[11] The WBGT is a heat index calculated by comprehensively evaluating air temperature, humidity, radiant heat, and wind speed using global temperature, natural wet bulb temperature, and natural dry bulb temperature. The UTCI is a thermal indicator that quantitatively predicts the risk of heat exposure on the human body; it calculates this by incorporating air temperature, humidity, wind speed, radiation temperature, metabolic heat production, and clothing thermal resistance values into the

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body thermal equilibrium formula. Although the WBGT and UTCI are reliable indices, it is time-consuming and difficult to carry out such calculations for an individual, school, or company.

Previous studies have reported on the increased number of emergency calls made during heat waves. Emergency calls increased by 20% as the mean daily maximum temperature increased 1°C in Toronto, Canada in 2005.[12] In Adelaide, Australia, maximum temperatures exceeded 35°C for 3 days; the number of emergency transportation incidents increased by 4%.[13] In Sydney, Australia, in 2011, emergency calls increased 14% during a heat wave.[14] In Japan, there have also been studies of the relationship between emergency transportation for heat-related diseases and the climate.[15-18] However, few nationwide investigations of emergency transportation linked to heat-related illness have been carried out in Japan. In this study, therefore, we investigated the relationship between two meteorological parameters and emergency transportation for heat-related symptoms. The meteorological parameters used in this study were the daily maximum temperature and the daily mean relative humidity since these measurements are easy for individuals to understand and use.

Methods

Ethical approval

The Ethical Committee of Nara Medical University approved the study design (authorization Code: 1483).

Study period and setting

The investigation period for this study spanned from June to September in 2010, 2011, and 2012. The study investigated Japan's 47 prefectural capital cities. To assess the results by district, the cities were grouped into 11 districts, as set forth on official Japanese government websites including that of the Japan Meteorological Agency.[19] The specifics of each of these 11 districts are as follows: Hokkaido is the second largest island and northernmost prefecture in Japan; Tohoku region consists of six prefectures – Aomori, Iwate, Miyagi, Akita, Yamagata, and Fukushima; Kanto region consists of seven prefectures – Ibaragi, Tochigi, Gunma, Saitama, Chiba, Tokyo, and Kanagawa; Hokuriku region consists of four prefectures – Niigata, Toyama, Ishikawa, and Fukui; Koshin region consists of two prefectures – Yamanashi and Nagano; Tokai region consists of four prefectures – Gifu, Shizuoka, Aichi, and Mie; Kinki region consists of seven prefectures – Shiga, Kyoto, Osaka, Hyogo, Nara, and Wakayama; Sanin region consists of two prefectures – Tottori and Shimane; Sanyo region consists of three prefectures – Okayama, Hiroshima, and Yamaguchi; Shikoku region consists of four prefectures – Tokushima, Kagawa, Ehime, and Kochi; and Kyusyu region consists of eight prefectures – Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, and Okinawa.

Emergency transportation data

Data from the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications were used to obtain the number of patients requiring emergency transportation for heat-related diseases in the investigated districts from June to September in 2010–2012. These data included information on the daily number of patients requiring emergency transportation for heat-related illness in each district and the age groups of those patients (newborns: <28 days, infants: ≥28 days and <7 years, children: ≥7 years and <18 years, adults: ≥18 years and <65 years, and elderly persons: ≥65 years). The data on patients who required emergency transportation for heat-related diseases were collected by the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications.

In this study, newborns and infants were excluded because the number of cases of emergency transportation required for infants aged six or younger was extremely small.

Data on meteorological phenomena

Data detailing the daily maximum temperature and mean daily relative humidity during the study period (and for the past 10 years) were obtained from the Japan Meteorological Agency, where records from the nearest weather stations in the prefectural capital cities were collected.

Analytical method

The mean daily maximum temperatures during the study period and for the past 10 years were shown as arithmetical means of the daily maximum temperatures for individual periods.

The daily number of emergency transportation cases linked to heat-related illness in children, adults, and elderly persons was calculated as the number of emergency transportation incidents per 100,000 people in the population. To create the analytical data set for this study, the number of emergency transportation cases per 100,000 people in each age group and the daily meteorological data were combined with data on emergency transportation due to heat-related diseases in the 47 prefectures.

To investigate the relationship between the number of emergency transportation cases due to heat-related diseases and the daily maximum temperature/relative humidity, the number of patients requiring emergency transportation per 100,000 children, adults, and elderly persons were used as outcome variables, whereas the daily maximum temperature and mean daily relative humidity were used as explanatory variables. Multiple regression analyses were conducted for the 11 districts.

We carried out the following analyses to investigate the relationship between the risk of incidents of heat-related disease and the daily maximum temperature. The daily maximum temperatures for the past 10 years in the 11 districts were classified into four categories, with cutoff points at the 50th, 75th, 95th, and higher than 95th percentiles. Using these four categories for the daily maximum temperatures observed during the study period, we conducted a logistical regression analysis to predict the presence or absence of emergency transportation due to heat-related diseases, with the categorized values of daily maximum temperatures as the independent variables. With the 50th percentile serving as the reference category for each area, the transportation risks in each temperature category were analyzed.

In the 47 cities considered, a day when patients with heat-related diseases required emergency transport was counted as a day of heat prostration. A day when no patients with heat-related diseases required emergency transport was not counted. Emergency transportation for patients with heat-related diseases was an objective variable, whereas the daily maximum temperature was an explanatory variable. Logistic regression analyses were conducted in 11 districts.

In addition, area under the curve values were calculated using receiver operating characteristic (ROC) curves for daily maximum temperature. Cutoff points, using the Youden index, were calculated for sensitivity and specificity.

SPSS and JMP® version 11.2 (SAS Institute Inc., Cary, NC, USA) was used for all analyses. Differences were judged to be statistically significant where $P < 0.05$.

Results

Temperature by districts

Table 1 shows the mean daily maximum temperature during the study period (°C) and the mean daily maximum temperatures for the past 10 years (°C) in the 11 Japanese districts examined in our study. As for regional differences in the daily maximum temperature, the southern districts of Japan tend to have higher temperatures; no substantial difference was found across western Japan, either during the study period or for the past 10 years. Comparing mean daily maximum temperatures for the past 10 years and the study period showed that study period temperatures were higher in all districts, apart from Shikoku.

Number of cases of emergency transportation by age group

Table 2 shows the number of people who required emergency transportation due to heat-related illness and the number of emergency transportation cases per 100,000 people in the separate age groups. In all of the examined districts, the number of emergency transportation cases per 100,000 people was highest among elderly people, followed by children and finally adults. Comparing the individual districts, the number of emergency transportation cases was higher in the Sanin and Tokai districts.

The results of the multiple regression analyses using meteorological parameters to predict the number of emergency transportation cases per 100,000 people by age group [Table 3] reveal that, for patients in each of the age groups, the partial regression coefficient was significant for daily maximum temperature. Mean daily relative humidity was significant only for children in Kinki district, adults in Sanyo and Kyushu districts, and elderly people in Kanto and Tokai districts. Comparing the impact of daily maximum temperature and mean daily relative humidity on the number of patients requiring emergency transportation for heat-related illness, the standardized partial regression coefficients revealed that daily maximum temperature was a stronger predictor across all districts and age groups, whereas mean daily relative humidity had a relatively weak influence. The increase in the number of emergency transportation cases due to heat-related diseases per 100,000 people, corresponding to a 1.0°C increase in the daily maximum temperature, ranged from 0.016 (in Hokkaido) to 0.106 (in Sanin) among children, from 0.013 (in Hokkaido) to 0.059 (in Sanin) among adults, and from 0.045 (in Hokkaido) to 0.159 (in Tokai) among elderly persons.

Increase in emergency transportation cases due to heat-related diseases

Table 4 shows the risk of emergency transportation due to heat-related diseases, given daily maximum temperatures at

Table 1: Mean daily maximum temperature for the study period and the past 10 years

Districts	Mean daily maximum temperature for the study period (°C)			Mean daily maximum temperature for the past 10 years (°C)		
	Mean ± SD	Minimum value	Maximum value	Mean ± SD	Minimum value	Maximum value
Hokkaido	25.5 ± 4.0	13.6	34.1	24.1 ± 2.3	18.1	29.6
Tohoku	28.0 ± 4.7	13.4	37.7	26.4 ± 2.7	19.2	34.0
Kanto	29.7 ± 4.4	14.9	39.8	28.4 ± 2.5	20.9	34.5
Hokuriku	29.6 ± 4.1	17.4	37.6	28.5 ± 2.6	22.2	34.5
Koshin	30.2 ± 4.3	16.7	38.1	29.3 ± 2.8	20.6	35.3
Tokai	30.2 ± 3.8	15.9	38.0	29.8 ± 2.5	22.8	35.8
Kinki	30.5 ± 3.8	17.7	38.1	30.2 ± 2.5	21.9	35.5
Sanin	30.3 ± 4.1	20.0	38.4	29.3 ± 2.5	23.3	35.0
Sanyo	30.6 ± 3.6	19.2	37.9	30.3 ± 2.3	23.9	34.8
Shikoku	30.4 ± 3.5	20.1	36.8	30.2 ± 2.3	24.1	34.5
Kyushu	30.3 ± 3.4	19.4	37.8	30.5 ± 2.2	24.0	35.6

The mean daily maximum temperatures for the individual periods were added and avaraged. The minimum and maximum values are the lowest and the highest values of the daily maximum temperatures for the individual periods, respectively. Study period: The periods from June to September in 2010–2012; The past 10 years: the periods from June to September in 2000–2011. SD: Standard deviation.

Table 2: Number of emergency transports because of heat-related diseases (June to September in 2010–2012)

Districts	Children (aged 7–17 years)		Adults (aged 18–64 years)		Elderly persons (aged ≥65 years)		Total	
	Number of transports	Number of transports per 100,000 children	Number of transports	Number of transports per 100,000 adults	Number of transports	Number of transports per 100,000 elderly persons	Number of transports	Number of transports per 100,000 people
Hokkaido	46	24.1	246	19.8	256	65.3	548	30.0
Tohoku	384	127.6	1003	59.7	1266	215.8	2653	103.4
Kanto	1965	101.7	8106	62.9	7280	180.6	17,351	92.1
Hokuriku	323	149.6	909	77.1	918	203.8	2150	116.5
Koshin	90	108.0	195	46.5	251	147.2	536	79.6
Tokai	456	115.0	1811	79.7	2254	273.4	4521	129.4
Kinki	704	104.5	2854	68.8	3197	208.7	6755	106.3
Sanin	84	169.9	248	98.2	261	246.5	593	145.4
Sanyo	339	135.4	900	68.3	883	195.0	2122	105.0
Shikoku	255	142.8	572	60.3	711	196.9	1538	103.4
Kyushu	712	126.7	1788	59.7	1664	171.0	4164	91.9
Total	5358	110.9	18,632	63.5	18,941	191.7	42,931	97.5

the 75th, 95th, and higher than 95th percentiles. The reference category was the 50th percentile, for mean daily maximum temperatures over the past 10 years. When the daily maximum temperatures were higher than the mean daily maximum temperatures for the past 10 years, the demand for emergency transportation was higher across all age groups – children, adults, and elderly persons. Starting at the 50th percentile of the daily maximum temperature, when the temperature increased by about 1.5°C (to the 75th percentile), in each of the 11 districts, the demand for emergency transportation due to heat-related illness became higher. The range of increase in this risk was 2.4–4.6 times among children, 3.0–8.9 times among adults, and 2.7–6.6 times among elderly people. Moreover, when the daily maximum temperatures reached the 95th percentile or higher, the risk increased 20 times or more in many districts.

Relationship between emergency transportation for heat-related diseases and daily maximum temperature

Table 5 shows the presence/absence of patients requiring emergency transport for heat-related diseases. It also shows the results of the logistic regression analyses for daily maximum temperature by days. The highest odds ratio (a 95% confidence interval) was 1.643 (1.534–1.769) in the Sanin district, followed by 1.626 (1.564–1.693) in the Kinki district and 1.615 (1.529–1.711) in the Sanyo district.

The cutoff values obtained from ROC curves using the daily maximum temperature were highest at 31.3°C in Sanyo district and lowest at 26.6°C in Hokkaido district. Across Japan, the cutoff value for the central part of the country tended to be the highest [Table 6].

Discussion

In this study, the 50th percentile of the mean daily maximum temperature from June to September for the past 10 years was used as the mean daily maximum temperature for these months. We found that the demand for emergency transportation due to heat-related diseases rose in accordance with an increase in the daily maximum temperature to the 75th, 95th, and higher than 95th percentiles. In multiple regression models that used the daily maximum temperature and mean daily relative humidity to predict cases of emergency transportation due to heat-related diseases, the daily maximum temperature had a more significant impact than daily relative humidity in most of the examined districts. Previous studies have reported a strong correlation between daily maximum temperature and an increase in emergency transportation cases.[20,21] Reports from hospitals including emergency hospitals, hospital visits,[14] and the risk of hospitalization[22] have increased during heat waves. Strong correlations have also been reported between the annual mean temperature deviation and the consultation rate.[23] These reports indicate that the incidence of heat-related illness is greatly influenced by increases in temperature. To warn the public about the risk of heat-related diseases, heat indices have been developed in some countries.[24-26] These indices take both relative humidity and temperature into consideration.

The adjusted R^2 of the multiple regression analysis in our study was low. Adding other meteorological parameters such as wind speed, atmospheric pressure, and cloud cover into the explanatory variables may improve predictions of the number of emergency transportation cases due to heat-related disease. However, personal factors, such as patients' medical histories and whether they were indoors or outdoors, can also affect the incidence of heat-related diseases. Such detailed information about patients who required emergency transportation for heat-related diseases is not included in the nationwide database. Further research, incorporating these data, will clarify the relationship between meteorological parameters and emergency transportation for heat-related symptoms.

The results of the present study indicate that, for each 1.0°C increase in the daily maximum temperature, the number

Table 3: Relationship between daily maximum temperature/mean daily relative humidity and emergency transports per 100,000 people, by age group

Districts	Maximum temperature/relative humidity	Children (aged 7–17 years)					Adults (aged 18–64 years)				
		β	Standardized β	95% *CI*		Adjusted R^2	β	Standardized β	95% *CI*		Adjusted R^2
				Lower limit	Upper limit				Lower limit	Upper limit	
Hokkaido	DHT	0.016	0.291†	0.010	0.021	0.076	0.013	0.463†	0.011	0.016	0.213
	MDRH	0.001	0.031	−0.002	0.003		0.000	−0.015	−0.001	0.001	
Tohoku	DHT	0.061	0.245†	0.050	0.072	0.062	0.036	0.443†	0.033	0.039	0.183
	MDRH	−0.002	−0.014	−0.007	0.004		0.002	0.039	0.000	0.003	
Kanto	DHT	0.083	0.302†	0.072	0.095	0.090	0.043	0.509†	0.040	0.046	0.268
	MDRH	0.000	0.001	−0.006	0.006		−0.001	−0.022	−0.003	0.001	
Hokuriku	DHT	0.077	0.241†	0.059	0.096	0.054	0.047	0.456†	0.041	0.052	0.220
	MDRH	0.002	0.013	−0.007	0.011		−0.001	−0.03	−0.004	0.001	
Koshin	DHT	0.066	0.160†	0.032	0.099	0.021	0.026	0.373†	0.021	0.032	0.121
	MDRH	0.004	0.018	−0.014	0.022		0.002	0.056	−0.001	0.005	
Tokai	DHT	0.086	0.267†	0.068	0.105	0.076	0.055	0.453†	0.049	0.061	0.215
	MDRH	−0.003	−0.022	−0.010	0.004		−0.001	−0.025	−0.004	0.001	
Kinki	DHT	0.080	0.302†	0.068	0.092	0.080	0.047	0.504†	0.043	0.051	0.240
	MDRH	0.005	0.047*	0.000	0.010		0.001	0.029	0.000	0.003	
Sanin	DHT	0.106	0.206†	0.062	0.151	0.043	0.059	0.403†	0.048	0.071	0.184
	MDRH	−0.003	−0.013	−0.025	0.018		−0.003	−0.048	−0.009	0.002	
Sanyo	DHT	0.088	0.257†	0.066	0.110	0.064	0.054	0.474†	0.047	0.061	0.200
	MDRH	0.001	0.004	−0.009	0.010		0.003	0.061*	0.000	0.006	
Shikoku	DHT	0.090	0.235†	0.069	0.111	0.049	0.041	0.391†	0.035	0.046	0.140
	MDRH	0.004	0.032	−0.003	0.012		0.002	0.041	0.000	0.004	
Kyushu	DHT	0.083	0.293†	0.071	0.094	0.076	0.041	0.405†	0.037	0.045	0.150
	MDRH	0.004	0.038	0.000	0.008		0.001	0.038*	0.000	0.003	

Districts	Elderly persons (≥65 years)				
	β	Standardized β	95% *CI*		Adjusted R^2
			Lower limit	Upper limit	
Hokkaido	0.045	0.485†	0.036	0.054	0.234
	−0.001	−0.014	−0.004	0.003	
Tohoku	0.127	0.491†	0.117	0.138	0.230
	0.004	0.028	−0.002	0.009	
Kanto	0.125	0.495†	0.116	0.134	0.277
	−0.009	−0.065†	−0.013	−0.004	
Hokuriku	0.121	0.462†	0.108	0.135	0.223
	−0.003	−0.022	−0.009	0.004	
Koshin	0.074	0.364†	0.058	0.089	0.130
	0.000	0.000	−0.008	0.008	
Tokai	0.159	0.483†	0.142	0.175	0.276
	−0.010	−0.080†	−0.017	−0.004	
Kinki	0.142	0.516†	0.131	0.153	0.252
	0.004	0.031	−0.001	0.008	
Sanin	0.150	0.409†	0.121	0.179	0.194
	−0.010	−0.057	−0.024	0.004	
Sanyo	0.127	0.483†	0.111	0.142	0.228
	0.001	0.009	−0.005	0.007	
Shikoku	0.132	0.434†	0.116	0.148	0.177
	0.003	0.028	−0.003	0.009	
Kyushu	0.110	0.442†	0.100	0.119	0.184
	0.002	0.026	−0.001	0.006	

Results of multiple regression analyses in which the numerical values of emergency transports because of heat-related diseases per 100,000 people in each age group were used as the dependent variables and the daily maximum temperatures and mean daily relative humidities were used as explanatory variables. *$P<0.05$; †$P<0.01$. DHT: Daily highest temperature; MDRH: Daily mean daily relative humidity; *CI*: Confidence interval.

Table 4: Daily maximum temperatures and risk of emergency transport because of heat-related diseases

Districts	Percentile	Daily maximum temperature	Children (aged 7–17 years)			Adults (aged 18–64 years)			Elderly persons (aged ≥65 years)		
			Odds	95% *CI*		Odds	95% *CI*		Odds	95% *CI*	
				Lower limit	Upper limit		Lower limit	Upper limit		Lower limit	Upper limit
Hokkaido	0–49th	18.1°C–24.1°C		Reference category			Reference category			Reference category	
	50th–74th	24.2°C–25.7°C	5.40	0.96	30.49	2.95	1.19	7.32*	0.67	0.24	1.91
	75th–94th	25.8°C–27.6°C	3.85	0.69	21.56	4.29	1.92	9.61†	3.02	1.49	6.11†
	≥95th	27.7°C–29.6°C	17.45	4.03	75.51†	14.16	6.90	29.06†	10.47	5.61	19.55†
Tohoku	0–49th	19.2°C–26.4°C		Reference category			Reference category			Reference category	
	50th–74th	26.5°C–28.1°C	1.81	0.90	3.67	5.83	3.23	10.54†	6.63	4.10	10.72†
	75th–94th	28.2°C–30.3°C	3.85	2.21	6.69†	12.42	7.34	21.01†	9.24	5.94	14.39†
	≥95th	30.4°C–34.0°C	11.33	7.11	18.03†	41.15	25.24	67.09†	38.26	25.54	57.31†
Kanto	0–49th	20.9°C–28.7°C		Reference category			Reference category			Reference category	
	50th–74th	28.8°C–30.1°C	2.92	1.95	4.40†	4.02	2.96	5.44†	2.82	2.06	3.87†
	75th–94th	30.2°C–32.0°C	6.55	4.71	9.10†	7.72	5.93	10.04†	6.94	5.34	9.03†
	≥95th	32.1°C–34.5°C	15.50	11.57	20.78†	22.50	17.61	28.75†	24.27	18.95	31.10†
Hokuriku	0–49th	22.2°C–28.8°C		Reference category			Reference category			Reference category	
	50th–74th	28.9°C–30.4°C	4.61	2.29	9.26†	3.36	1.96	5.76†	4.82	3.00	7.73†
	75th–94th	30.5°C–32.5°C	11.10	6.24	19.76†	13.77	9.00	21.08†	8.40	5.59	12.61†
	≥95th	32.6°C–34.5°C	13.65	7.96	23.41†	27.59	18.57	41.00†	22.39	15.45	32.44†
Koshin	0–49th	20.6°C–29.5°C		Reference category			Reference category			Reference category	
	50th–74th	29.6°C–31.2°C	1.04	0.21	5.21	8.93	3.58	22.27†	5.12	2.35	11.16†
	75th–94th	31.3°C–33.4°C	3.60	1.25	10.32*	11.31	4.80	26.67†	10.10	5.08	20.09†
	≥95th	33.5°C–35.3°C	10.66	4.40	25.83†	29.90	13.43	66.55†	18.97	9.99	36.00†
Tokai	0–49th	22.8°C–30.0°C		Reference category			Reference category			Reference category	
	50th–74th	30.1°C–31.6°C	3.75	2.26	6.20†	3.64	2.54	5.22†	2.65	1.89	3.71†
	75th–94th	31.7°C–33.6°C	5.71	3.66	8.91†	10.08	7.30	13.91†	8.37	6.16	11.35†
	≥95th	33.7°C–35.8°C	18.71	12.15	28.81†	29.73	20.28	43.56†	22.07	15.21	32.03†
Kinki	0–49th	21.9°C–30.4°C		Reference category			Reference category			Reference category	
	50th–74th	30.5°C–32.0°C	3.93	2.57	6.00†	4.90	3.67	6.53†	5.87	4.41	7.82†
	75th–94th	32.1°C–33.8°C	7.38	5.08	10.71†	9.24	7.06	12.10†	10.19	7.78	13.36†
	≥95th	33.9°C–35.5°C	17.32	12.19	24.61†	26.30	19.67	35.16†	26.89	20.09	35.98†
Sanin	0–49th	23.3°C–29.3°C		Reference category			Reference category			Reference category	
	50th–74th	29.4°C–31.1°C	2.16	0.36	0.00	3.86	1.52	0.00†	3.19	1.36	0.00†
	75th–94th	31.2°C–33.1°C	7.95	2.07	30.53†	10.27	4.63	22.76†	8.82	4.31	18.06†
	≥95th	33.1°C–35.0°C	28.09	8.63	91.47†	34.58	16.95	70.56†	27.58	14.63	52.00†
Sanyo	0–49th	23.9°C–30.4°C		Reference category			Reference category			Reference category	
	50th–74th	30.5°C–32.3°C	3.11	1.80	5.40†	5.20	3.39	7.99†	5.34	3.51	8.11†
	75th–94th	32.4°C–33.7°C	6.35	3.87	10.43†	14.64	9.62	22.27†	11.00	7.31	16.55†
	≥95th	33.8°C–34.8°C	12.88	8.12	20.42†	23.97	15.82	36.31†	22.32	14.84	33.57†
Shikoku	0–49th	24.1°C–30.5°C		Reference category			Reference category			Reference category	
	50th–74th	30.6°C–32.0°C	2.41	1.35	4.33†	4.68	3.02	7.26†	4.81	3.14	7.37†
	75th–94th	32.1°C–33.2°C	4.26	2.54	7.16†	8.16	5.39	12.35†	10.32	6.91	15.41†
	≥95th	33.3°C–34.5°C	8.43	5.43	13.11†	17.59	12.10	25.58†	21.51	14.87	31.11†
Kyushu	0–49th	24.0°C–30.8°C		Reference category			Reference category			Reference category	
	50th–74th	30.9°C–32.1°C	3.14	2.29	4.31†	3.46	2.72	4.41†	3.82	2.99	4.89†
	75th–94th	32.2°C–33.5°C	6.09	4.51	8.23†	6.78	5.30	8.66†	7.76	6.05	9.96†
	≥95th	33.6°C–35.6°C	9.24	6.99	12.21†	14.42	11.34	18.34†	18.52	14.45	23.73†

We calculated threshold temperatures as the 50th, 75th, 95th, and >95th percentiles of the daily maximum temperatures for the past 10 years. In logistic regression analyses, presence or absence of emergency transport because of heat-related diseases during the study period was the dependent variable. The percentile divisions of the daily maximum temperatures (50th, 75th, 95th, and >95th percentiles) based on the four percentile divisions calculated from the daily maximum temperatures for the past 10 years were used as explanatory variables. The risk was calculated, with the 50th percentile serving as the reference category. **P*<0.05; †*P*<0.01. *CI*: Confidence interval.

of patients requiring emergency transportation due to heat-related illness increased most among elderly persons, followed by children and finally adults. As a general change induced by aging in elderly people, body temperature adjustment declines because of decreased physical reserve capacity and decreased temperature sensitivity in terms of exposure to heat. Children are immature when it comes to physical function development. Thus, children and elderly people are particularly vulnerable to heat stress, as the present results indicate. Studies from Australia[14,27]

Table 5: Proportions (odds ratios) of increases in persons requiring emergency transport for heat-related diseases for daily maximum temperature increases of 1°C

Districts	Odds ratio	95% *CI*		*P*
		Lower limit	Upper limit	
Hokkaido	1.453	1.340	1.589	<0.0001
Tohoku	1.470	1.423	1.521	<0.0001
Kanto	1.512	1.465	1.562	<0.0001
Hokuriku	1.523	1.460	1.591	<0.0001
Koshin	1.411	1.333	1.500	<0.0001
Tokai	1.534	1.468	1.606	<0.0001
Kinki	1.626	1.564	1.693	<0.0001
Sanin	1.643	1.534	1.769	<0.0001
Sanyo	1.615	1.529	1.711	<0.0001
Shikoku	1.604	1.525	1.692	<0.0001
Kyushu	1.556	1.503	1.612	<0.0001

CI: Confidence interval.

Table 6: Results of ROC curve analyses and cut-off points for maximum temperatures causing emergency transport of patients with severe heat-related diseases

Districts	Cut-off point for maximum temperature (°C)	Sensitivity (%)	Specificity (%)	AUC
Hokkaido	26.6	68.6	77.8	0.81
Tohoku	29.0	79.0	75.9	0.85
Kanto	30.3	75.6	82.2	0.86
Hokuriku	31.0	75.4	80.0	0.85
Koshin	30.6	85.0	65.8	0.80
Tokai	31.1	70.4	82.8	0.84
Kinki	29.8	85.9	70.1	0.86
Sanin	31.2	84.0	77.7	0.88
Sanyo	31.3	75.6	79.1	0.85
Shikoku	30.7	82.9	68.9	0.83
Kyushu	30.7	77.9	71.0	0.82

ROC: Receiver-operating characteristic; AUC: Area under curve.

and China[28] have reported that, among those calling for emergency assistance or visiting hospitals during heat wave periods, there is an elevated number of children and elderly patients.

Segmenting the Japanese results by district showed that cases of emergency transportation due to heat-related illness occurred most frequently in the Tokai district. The climate in the Tokai district is classified as belonging to the "inland" category in Japan's context-specific system of climate categorization. The district includes a mountain chain between adjacent regions. Tokai is known to be very hot in the summer because westerly winds from the Pacific Ocean are warmed by the Foehn phenomenon. In addition, the Tokai District includes Nagoya, which is a large city, therefore the heat island phenomenon further increases heat stress. These facts suggest that predictive factors for the occurrence of heat-related diseases may include topographical backgrounds that are unique to particular districts. Many reports have described heat prostration as a pathological condition related to heat, noting that the risk of its occurrence increases in accordance with increases in temperature. In addition, various factors, such as patients' health conditions, living environments, residential characteristics, and geographic/topographic conditions, can act as triggers for heat-related illness.

Previous studies of deaths and consultation numbers associated with heat-related diseases have reported that death or the risk of death increases[29-31] and that the number of patients visiting hospitals[32] or calling for emergency services[16] increases when the temperature exceeds a certain threshold. Even a 1.5°C increase above the mean daily maximum temperature (75th percentile) increases demand for emergency transportation due to heat-related diseases by 2.4–8.9 times. When the daily maximum temperature is at the 95th percentile or higher, this risk increases by 20 times or more. Naturally, it can be inferred that the higher the daily maximum temperature, the higher the severity of heat-related diseases.

Regarding the predictive factors used to determine the severity of heat-related diseases, previous work has reported that independent risk factors for death caused by heat prostration include being elderly, being institutionalized and elderly, having cardiac diseases, living alone, and being confined to bed.[33-35] Independent protective factors have been found to include the presence of air-conditioning equipment and being able to move to a place where air-conditioning equipment is present.[34,35] However, in surveys of elderly persons in Japan, only 11.8% of the respondents have stated that cooling equipment was turned on when the temperature exceeded 28°C.[36] Taken together, these earlier findings show that elderly people are susceptible to heat-related illness because they cannot accurately understand information, given their reduced physical abilities (including visual and auditory perception) and habit factors, such as being unfamiliar with information technology, and having poor access to air conditioners. It is important for public health organizations and health-care services to inform elderly people (or those making decisions on their behalf) about their susceptibility to heat. Such actions will have a positive impact on the prevention of heat-related diseases.

This study found that the number of cases of emergency transportation for patients with heat-related diseases rose with the daily maximum temperature in all districts in Japan. The cutoff value for daily maximum temperature associated with emergency transportation of patients ranged from 26.6°C in Hokkaido district to 31.3°C in Sanyo district. In Hokkaido and Tohoku districts, where the climate is relatively cool for Japan, patients required emergency transportation for heat-related diseases at lower temperatures than in other districts. The difference in mean daily maximum temperature and inflection point temperature was within 1.5°C in every district. During summer in Japan, it quite common for the daily maximum temperature to exceed 30°C, especially in July and August. Thus, preventive measures against heat should be taken, not only on very hot days but also on ordinary days.

This study has several limitations. First, because the meteorological data were observed values collected at weather stations in cities used as representative points, there is a possibility that the actual temperatures may not be reflected in these data because of factors such as the heat island phenomenon. Second, the diagnoses made for patients following emergency transportation for heat-related illness represented the expert opinions of physicians carrying out initial examinations, rather than definitive diagnoses. The symptoms of patients transported in ambulances for heat-related diseases ranged from mild to severe. They not only included severe symptoms such as hyperthermia, loss of consciousness, and organ failure caused by dehydration but also mild symptoms including general fatigue and mild headaches. These findings have affected the rest of our study, showing that temperature is more important than humidity. Third, patients who required emergency transportation due to heat-related illness were also influenced by personal factors including medical history, length of exposure to the heat environment, and activity intensity; as these factors were unknown, their influence on various pathological conditions could not be taken into consideration. Fourth, this study did not include patients with heat-related diseases who did not use ambulances to travel to the hospital. To clarify the relationship between the number of occurrences of heat-related diseases and meteorological conditions, future studies should include patients who do not use ambulances. However, this study, which used emergency transportation data from prefectural capital cities, has been the first to analyze data for entire districts in Japan.

In conclusion, in this study, we have analyzed nationwide emergency transportation linked to temperature- and heat-related diseases in Japan. The number of emergency transportation cases due to heat-related illness rises in accordance with increases in the daily maximum temperature. With an increase of about 1.5°C over the mean daily maximum temperature, the demand for emergency transportation increases by 2.4–8.9 times. Elderly people are an especially high-risk group for heat-related diseases. For this reason, public health organizations and health-care systems must be available and prepared to support them.

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Conflicts of interest

There are no conflicts of interest.

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