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 and between heat and diseases 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. Every summer, approximately 40,000 people call ambulances to request emergency transportation to hospitals due to heat-related illness.

Heat-related indices have been developed including the Wet Bulb Globe Temperature Index (WBGT) and the Universal Thermal Climate Index (UTCI). 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 index.

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Conclusion: Public health organizations and health-care services should support elderly people and children, two high-risk groups for heat-related diseases.

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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 Kypsuy 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 0.159 (in Tokai) among adults, from 0.013 (in Hokkaido) to 0.059 (in Sanin) among children, and from 0.005 (in Hokkaido) to 0.059 (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 averaged. 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   | 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 by days. The highest odds ratio 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) |
|-----------|---------------------------------------|-----------------------------|---------------------------|
|           | \( \beta \) | Standardized \( \beta \) | 95\% CI | Adjusted \( R^2 \) | \( \beta \) | Standardized \( \beta \) | 95\% CI | Adjusted \( R^2 \) |
|           | \( \beta \) |          | Lower limit | Upper limit |          |          | 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 | 0.000 -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 | 0.000 | 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) | \( \beta \) | Standardized \( \beta \) | 95\% CI | Adjusted \( R^2 \) |
|-----------|-----------------------------|--------------|-----------------|---------|---------------------|
|           | \( \beta \) |          | 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 relative humidity; CI: Confidence interval.
### Table 4: Daily maximum temperatures and risk of emergency transport because of heat-related diseases

| Districts          | Daily maximum temperature | Children (aged 7–17 years) | Adults (aged 18–64 years) | Elderly persons (aged ≥65 years) |
|--------------------|---------------------------|-----------------------------|---------------------------|----------------------------------|
|                    | Percentile | Odds | 95% CI | Percentile | Odds | 95% CI | Percentile | 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 | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 18.1°C–24.1°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 18.1°C–24.1°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 18.1°C–24.1°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Tohoku             | 0–49th     | 20.9°C–28.7°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 20.9°C–28.7°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 20.9°C–28.7°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 20.9°C–28.7°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Kanto              | 0–49th     | 29.6°C–31.2°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 29.6°C–31.2°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 29.6°C–31.2°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 29.6°C–31.2°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Hokuriku           | 0–49th     | 22.8°C–30.0°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 22.8°C–30.0°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 22.8°C–30.0°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 22.8°C–30.0°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Koshin             | 0–49th     | 26.0°C–29.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 26.0°C–29.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 26.0°C–29.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 26.0°C–29.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Tokai              | 0–49th     | 22.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 22.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 22.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 22.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Kinki              | 0–49th     | 21.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 21.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 21.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 21.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Sanin              | 0–49th     | 23.3°C–29.3°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 23.3°C–29.3°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 23.3°C–29.3°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 23.3°C–29.3°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Sanyo              | 0–49th     | 23.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 23.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 23.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 23.9°C–30.4°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Shikoku            | 0–49th     | 24.1°C–30.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 24.1°C–30.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 24.1°C–30.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 24.1°C–30.5°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
| Kyushu             | 0–49th     | 20.0°C–30.8°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 50th–74th  | 20.0°C–30.8°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | 75th–94th  | 20.0°C–30.8°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |
|                    | ≥95th      | 20.0°C–30.8°C | Reference category | Reference category | Reference category | Reference category | Reference category | Reference category |

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[4,27]
and China\textsuperscript{[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\textsuperscript{[29–31]} and that the number of patients visiting hospitals\textsuperscript{[32]} or calling for emergency services\textsuperscript{[16]} increases when the temperature exceeds a certain threshold. Even a 1.5°C increase above the mean daily maximum temperature (75\textsuperscript{th} 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 95\textsuperscript{th} 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.\textsuperscript{[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.\textsuperscript{[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.\textsuperscript{[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

### 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.
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 illnesses 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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There are no conflicts of interest.

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