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Spatial and temporal variation in emergency transport during periods of extreme heat in Japan: A nationwide study

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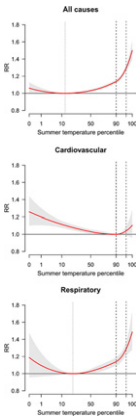
HIGHLIGHTS

- We estimated variations in the association of heat and emergency transport.
- We observed temporal variations in RRs for heat-related emergency transport.
- Spatial heterogeneity among prefectures was observed for emergency transport.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Several studies have reported the burden of climate change on extreme heat-related mortality or morbidity. However, few studies have investigated the spatial and temporal variation in emergency transport during periods of extreme heat on a national scale.
Methods: Daily emergency ambulance dispatch data from 2007 to 2010 were acquired from all 47 prefectures of Japan. The temporal variability in the relationship between heat and morbidity in each prefecture was estimated using Poisson regression combined with a distributed lag non-linear model and adjusted for time trends. The spatial variability in the heat-morbidity relationships between prefectures was estimated using a multivariate meta-analysis.
Results: A total of 5,289,660 emergency transports were reported during the summer months (June through September) within the study period. The overall cumulative relative risk (RR) at the 99th percentile vs. the minimum morbidity percentile was 1.292 (95% CI: 1.251–1.333) for all causes, 1.039 (95% CI: 0.989–1.091) for cardiovascular diseases, and 1.287 (95% CI: 1.210–1.368) for respiratory diseases. Temporal variation in the estimated effects indicated a non-linear relationship, and there were differences in the temporal variations between heat and all-cause and cause-specific morbidity. Spatial variation between prefectures was observed for all causes (Cochran Q test, $p < 0.001$; $I^2 = 45.8\%$); however, there was no significant spatial heterogeneity for cardiovascular (Cochran Q test, $p = 0.054$; $I^2 = 15.1\%$) and respiratory (Cochran Q test, $p = 0.681$; $I^2 = 1.0\%$) diseases.
Conclusions: Our nationwide study demonstrated differences in the spatial and temporal variations in the relative

Abbreviations: CI, confidence interval; ICD, International Classification of Diseases.

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risk for all-cause and cause-specific emergency transport during periods of extreme heat in Japan between 2007 and 2010. Our results suggest that public health strategies aimed at controlling heat-related morbidity should be tailored according to region-specific weather conditions.

1. Introduction

Extreme high temperature is the most prominent cause of weather-related health effects worldwide (Costello et al., 2009). Exposure to extreme heat has been associated with increased risks of morbidity and mortality in a wide range of countries and climates (Benmarhnia et al., 2015; Chung et al., 2015; Gasparrini et al., 2015b). Studies and reports involving projections of heat-related mortality in the future tend to reach the conclusion that risks will increase as the planet warms and heat events become longer, more intense, and more frequent, and understanding the spatial and temporal aspects of sensitivity is particularly important for generating accurate projections for the future (Bierbaum et al., 2013; Sheridan and Allen, 2015; Toloo et al., 2013). A number of studies have evaluated the public health impacts of extreme heat events and identified associations between high temperature and mortality (Basu and Samet, 2002). However, few studies have investigated the relationship between extreme high temperature and emergency transport. Many studies struggle to properly account for potential adaptation in quantifying the burden of climate change on heat-related mortality or morbidity. Thus, it is essential to focus on historical data for refining such estimates and helping to prioritize mitigation and adaptation strategies.

Emerging evidence suggests a correlation between extreme high temperature and use of emergency transport. Studies conducted in Canada have shown that ambulance response calls increase significantly with extreme high temperatures (Bassil et al., 2009; Bassil et al., 2011; Dolney and Sheridan, 2006). Similar associations were observed in ambulance call-outs during heat waves in Australia (Nitschke et al., 2011; Turner et al., 2013; Williams et al., 2012). In China, immediate effects of high temperature on emergency department visits and emergency ambulance dispatches have been reported (Sun et al., 2014). However, most of the studies discussed above examined high temperature impacts in a single city or region, and the results do not necessarily extend to the national level. The relationships between extreme temperatures and morbidity can be affected by the cause of morbidity and by regional, climatological, demographic, and temporal factors. In relation to adaptive management, public health officials are required to identify the severity of local areas and to develop prevention strategies (Bassil et al., 2009; Harlan et al., 2013; Hattis et al., 2012; Hondula and Barnett, 2014; Sheridan and Dolney, 2003; Vaneckova et al., 2010; Wolf et al., 2015). To this end, it is essential to evaluate changes in the spatial and temporal patterns of vulnerability to heat based upon detailed information such as the location and time of incidence.

Socio-economic, infrastructural, environmental, behavioral, and biophysical adaptations can affect an individual's vulnerability to heat (Stafoggia et al., 2006). Several studies have reported reduced short-term mortality due to extreme temperatures in areas where the population has adapted to highly variable ambient temperatures (Astrom et al., 2013; Bobb et al., 2014b; Boeckmann and Rohn, 2014; Ha and Kim, 2013; Kyselý and Plavcová, 2012). Other studies indicated that the high temperature-related mortality varied greatly from year to year, and there are uncertainties regarding the future prediction of heat-related mortality (Guo et al., 2012; Sheridan et al., 2009). A recent review study also found that studies based on projected changes in climate indicate substantial increases in heat-related mortality and morbidity in the future, whereas observational studies based on historical information of climate and human health show a decrease in negative impacts during recent warming (Hondula et al., 2015). Additionally, implementation of public health interventions, such as increasing awareness of the heat-related risk, may lead to reduced extreme temperature-related mortality over time (Donaldson et al., 2003; Ebi et al., 2006). These findings suggest that the relationship between temperature and morbidity is affected by demographic changes, variations in susceptibility factors, and the degree of adaptation to the local environment. However, few studies have investigated spatial and temporal variations in extreme temperature-related use of emergency transport.

In this study, spatial and temporal variations in the association between high temperature and all-cause and cause-specific emergency transport in the 47 prefectures of Japan were investigated using multivariate meta-regression combined with time-varying distributed lag non-linear modeling. To our knowledge, this is the first large-scale study in Japan to quantify spatial and temporal variation in the relationship between high temperature and emergency transport.

2. Methods

2.1. Data sources

Daily time-series data of emergency ambulance dispatches and weather variables in all 47 prefectures of Japan were obtained for the period 2007 to 2010 (Table 1). Under Japan's Fire Service Act, municipal governments provide emergency medical services at ~800 fire stations with dispatch centers. Morbidity data, obtained from the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications, included the date of the emergency ambulance dispatch and disease classification according to the primary codes of the *International Classification of Diseases* (10th revision, ICD-10). In Japan, registration of emergency ambulance dispatch data is required under the Fire Service Act. However, due to a lack of data on emergency ambulance dispatches in the Tokyo metropolitan area, this area was excluded from all

Table 1
Descriptive statistics of the study periods, total number of emergency transports, and daily distribution of emergency transports.

Causes (ICD-10 codes)	Period	Total cases	Mean prefecture-specific cases				
			Min	25th	Median	75th	Max
All causes (A00–Z99)	2007	1,177,150	158.9	188.9	201.9	217.5	297.5
	2008	1,288,182	176.4	208.6	222.4	239.2	292.5
	2009	1,338,106	183.7	218.5	232.4	246.7	297.1
	2010	1,486,222	197.8	237.8	256.4	276.9	345.8
Cardiovascular diseases (I00–I99)	2007	141,668	12.9	21.4	24.5	27.8	38.6
	2008	155,543	15.1	23.5	26.9	30.4	41.6
	2009	164,257	16.7	25.0	28.6	32.0	43.7
	2010	168,941	17.0	25.9	29.3	32.8	44.9
Respiratory diseases (J00–J99)	2007	64,247	4.3	8.9	10.9	13.2	20.9
	2008	68,806	4.6	9.7	11.9	14.2	21.2
	2009	79,259	5.5	11.2	13.6	16.1	25.6
	2010	86,244	6.2	12.4	14.8	17.4	26.3

Table 2
Descriptive statistics of the study periods and summer temperature distribution (°C).

	Period	Summer temperature (°C).				
		Min	25th	Median	75th	Max
Summer temperature (°C)	2007	17.6	23.1	25.0	27.2	31.0
	2008	16.0	22.4	24.9	27.2	30.2
	2009	18.1	22.3	24.3	26.2	29.3
	2010	17.4	23.6	26.3	28.7	31.0