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Trend of Outbreak of Thermal Illness Patients Based on Temperature 2002–2013 in Korea

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Abstract: Climate change can have serious impacts on human health, resulting in increased healthcare utilization. Many studies on the relationship between mortality and temperature exist, but few studies focus on heat related outbreaks. Our objective was to verify the relationship between ambient temperature and heat related illnesses during the summer months. This study analyzed the National Health Insurance Service (NHIS) database. Patients with an ICD-10 code T67 (Effects of Heat and Light) presenting between May and September were included. Generalized additive models (GAM) were used to determine the association between ambient temperature and heat related illnesses including differences by region and patient age. A total of 335,759 patients with heat related illnesses were identified from 2002 to 2013. The number of heat related illnesses increased from 14,994 in 2002 to 29,332 in 2013. For every 1 °C increase in the daily temperature above 29.5 °C, the number of patients with heat related illnesses also increased (RR 1.060; 95% CI, 1.059 to 1.061). In addition, a higher association between temperature and outbreaks of heat related to elderly patients (RR 1.084; 95% CI, 1.081 to 1.086) and rural patients (RR 1.229; 95% CI, 1.208 to 1.251) was identified. The association between the daily maximum temperature and outbreaks of heat related illness is identified. The number of patients with heat related illnesses increased over the years and was especially noted in elderly and rural patients.

Keywords: hot temperature; aged; rural

1. Introduction

Climate change is a continuing and rapid phenomenon happening all over the world. Changes are happening not only in temperature and precipitation, but also in the incidence, strength, and location of tornadoes and typhoons [1]. Furthermore, the rate of change is increasing [1]. The average temperature has increased 0.7 degrees from 1906 to 2005 [2]. In addition to increases in average temperature, increases in extreme temperatures, heat waves, are occurring [3,4]. The Korean climate is also rapidly changing. From 1971 to 2000, Korea has averaged 8.5 heat wave days per year, but this number is expected to rise to 32.3 days per year in the late 21st century by national mean temperature [5].

Heat waves are sporadic temperature elevations beyond the normal climate range of a specific region [6]. Heat related illnesses may occur when a person is exposed to heat such as heat wave for extended hours. Minor cases of heat illness include heat eczema, heat edema, and heat syncope, although these may progress to more serious cases, including heat spasm, heat exhaustion, and heatstroke [7].

Heat waves result in increased usage of community medical resources and if significant may outstretch the available resources [8]. Heat waves not only result in heat related illnesses, but also other illnesses not obviously associated with increased temperatures—including asthma and respiratory illnesses, insect-borne related, cardiovascular, cerebrovascular, and waterborne diseases [9–11].

Both the elderly and children are especially vulnerable to negative impacts of heat waves [12]. Children have large body surface compared to weight, and often have longer environmental exposures, thus making them more susceptible to heat waves. Elders have a higher burden of chronic disease and have comparatively low homeostatic function. Thus, they are prone not only to heat illnesses but also to aggravating pre-existing diseases leading to increase of medical resources [13–15].

Multiple reports describe the causes of deaths in Korea [16–19], but little evidence exists on outbreaks of heat related illnesses. The objective of this study was to identify trends in heat related illness outbreaks, investigate any identified increases, and to identify age groups at risk based on temperatures.

2. Methods

2.1. Study Design and Setting

South Korea is 99,720 km^2, and includes a population of 49.1 million. Korea is located between 33 and 43 degrees north latitude, in the eastern part of Asia, and has a cool temperature climate with four distinct seasons. Korea is influenced by the East Asian monsoon with precipitation of 388 mm to 1053.6 mm per year and daily mean temperatures during the summer months ranging from 23 to 26 °C [20]. Korea can be largely divided into six regions. Table 1 shows the details.

Table 1. Korean six regions.

Region	Area (km^2)	Population	Agricultural Population (%)	Weather Observatories
Central (Region 1)	11,818	25,258,000	0	9
Northeast (Region 2)	16,790	1,542,000	10.7	13
Northwest (Region 3)	16,615	5,275,000	9.5	11
Southwest (Region 4)	20,838	5,253,000	10.3	27
Southeast (Region 5)	32,278	13,218,000	5.7	29
Island (Region 6)	1849	593,000	13.9	4

2.2. Data Collection and Variables

This study analyzed health insurance data from the National Health Insurance Service (NHIS) database from 2002 to 2013 [21]. This health insurance service covers 98% of the Korean population, and the health insurance charged patients are approximately 46 million people, which is 90% of the resident registered population. This includes charge cases from 80,000 medical institutions (introduce Health Insurance Review & Assessment Service data). Medical institutions charge the NHIS a fee when a member receives care. The NHIS database is constituted of qualification and insurance fee database, treatment breakdown database, checkup database, medical care assistance database, and long-term care for the aged database. The NHIS database includes sociodemographic variables including date of birth, sex, age, residence, and type of insurance, and specifics of treatment including medical institution, major disease code, minor disease code and the start date of recuperation. A single patient can have up to six diagnosis codes in the database.

2.3. Environmental Data

Ambient temperatures (°C), relative humidity (%), and wind speed from 2002 to 2013 were obtained from the Korean Meteorological Administration. Maximum temperature, mean relative humidity and wind speed were taken hourly from 93 observatories across the country. The maximum temperature for the day was calculated as the average of the highest temperature for the day from each of the observatories and humidity and wind speed were calculated similarly as the average of all reporting observatories. The number of observatories varied between regions (Table 1).

To measure air quality, 24-h particulate matter (PM10) and ozone (O_3) concentrations were obtained from the Korean National Institute of Environmental Research. The Korean National Institute of Environmental Research collects data from 506 measuring stations in 97 cities and districts. PM10 and O_3 concentrations are measured every 15 min. Hourly averages were used for study purposes [22].

2.4. Study Population

This study identified patients with heat related illnesses based on ICD-10 codes using the NHIS' health insurance data. This database includes all hospital inpatients and outpatients. Heat related illness included all patients with ICD-10 diagnosis of T67.ICD-10 code T67 is further categorized into heat syncope, heat edema, heat cramp, heat exhaustion, and heat stroke. Eligible patients were included if they presented from the months May to September from 2002 to 2013.

2.5. Statistical Analysis

The relationship between heat wave patients and temperature is typical a U, V, or J shape [23,24] and increases as the number of heat wave patients on a specific temperature [25] A generalized additive model (GAM) with a Poisson distribution was used to evaluate the relationship between daily maximum temperatures and patients with heat related illness [25–27]. The widely used GAM method is a flexible and effective technique for conducting nonlinear regression analysis in time-series studies of the health effects of weather [28,29]. We controlled for the following confounding variables: relative humidity, wind speed, PM10, O_3, year, day of the week, and long term time trends.

$$\begin{aligned} \text{Log}\ (E(Y)) &= \beta 0 + \beta\ (\text{temperature} - 29.5\ ^{\circ}\text{C}) + \text{NS1}(\text{relative humidity}) \\ &+ \text{NS2}(\text{wind speed}) + \text{NS3}(\text{PM10}) + \text{NS4}(O_3) + \text{NS5}(\text{date}) \\ &+ \text{factor}(\text{year}) + \text{factor}(\text{day of the week}) \end{aligned}$$

E(Y) is the daily number of patients with heat related illnesses, β0 is the absolute value; β is the coefficient of maximum temperature −29.5 °C; NS1–NS5 are the natural cubic spline smoothing functions of relative humidity, wind speed, PM10, O_3, date(long term time trends); and factor is the indicator variable for year, day of the week.

The threshold temperature was set at 90% of the maximum daily temperature during the study period, based on findings from a previous study in Seoul [30]. We calculated the Relative Risk (RR) for each 1 °C rise in temperature above 29.5 °C [15].

Age was categorized into the following: infant to preschooler (0–7 years), schooler (8–17 years), young adult (18–44 years), middle adult (45–64 years), and elderly (over 65 years of age). Lag was checked from one to three days.

3. Results

A total of 335,759 patients (female: 186,781, 55.6%) were identified during the study period. The number of patients increased from 14,994 in 2002 to 29,332 in 2013. Age group distribution showed 65,998 (19.7%) for ages 0 to 7 years; 27,386 (8.2%) for ages 8 to 17 years; 83,502 (24.9%) for ages 18 to 44 years; 81,829 (24.4%) for ages 45 to 64 years; and 77,044 (22.9%) for ages over 65 years. Cases were distributed as Table 2.

During the study months over the years 2002 to 2013, the daily national-highest temperature was 26.2 °C, daily average temperature 21.8 °C, and the daily lowest temperature was 18.0 °C. The maximum of highest temperature was 34.5 and the minimum of lowest temperature was 12.9 (Table 3).

The number of patients with heat related illnesses increased as the daily highest temperature increased one degree above 29.5 °C (RR 1.060; 95% confidence interval (CI), 1.059 to 1.061). This finding was identified across all regions and by genders and age groups as in Table 4. We analyzed heat related illness patients number with relative humidity (RR 0.998; 95% CI, 0.998 to 0.999) and wind speed (RR 0.991; 95% CI, 0.984 to 0.998) also but, there was no meaningful result. We determined the relationship between the highest temperature one day before (lag 1) to three days before (lag 3) and patients with heat related illnesses. The lag effect as time passed showed in Table 4 which showing decrease in the effect as the time passed. Lag effect was also checked in different sex, age range, and regions, and all showed decrease effect as time passed (Table 4).

To help to understand the increase of the number of patients with heat related illnesses, Appendix A (Table A1) shows Korean population change, maximum temperature of the year, and number of days above threshold (Figure 1).

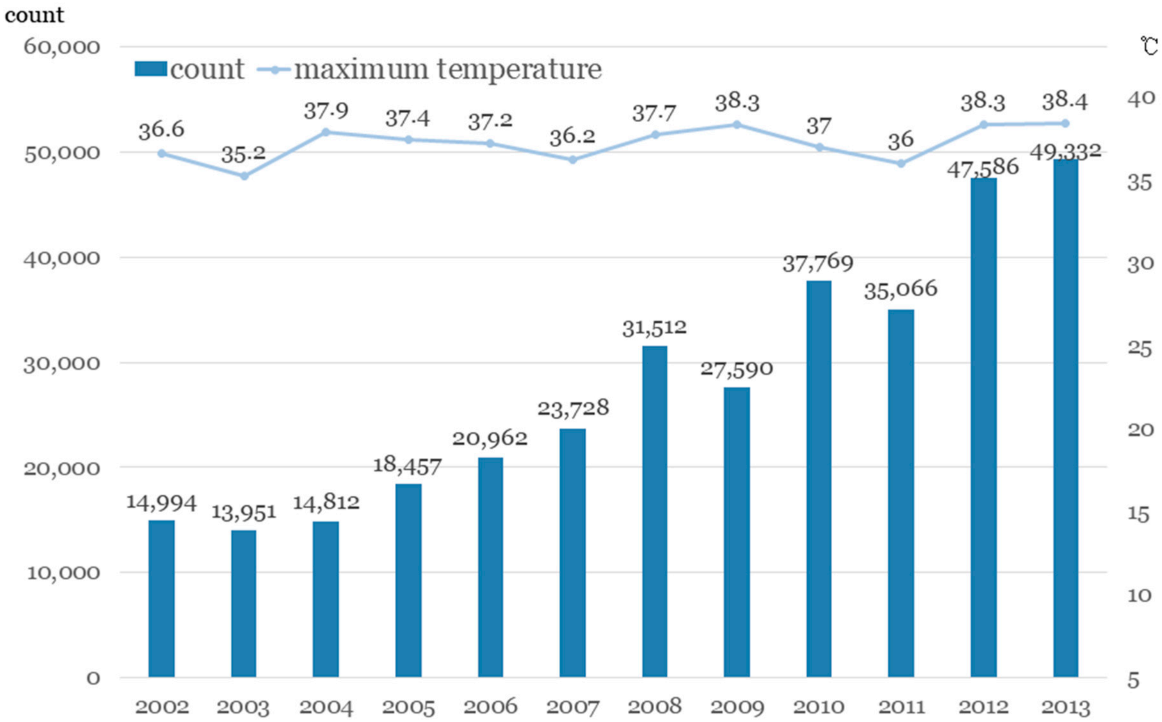

Figure 1. Trend of thermal illness patients and maximum temperature of the year from 2002 to 2013.

Table 2. Baseline characteristics of thermal illness patients from 2002 to 2013 in Korea.

Variables		Total		Region 1		Region 2		Region 3		Region 4		Region 5		Region 6	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Total		335,759	100.0	105,226	100.0	6450	100.0	65,199	100.0	68,176	100.0	86,715	100.0	3993	100.0
Year	2002	14,994	4.5	5748	5.5	334	5.2	3281	5.0	3246	4.8	2288	2.6	97	2.4
	2003	13,951	4.2	5882	5.6	324	5.0	3220	4.9	2674	3.9	1741	2.0	110	2.8
	2004	14,812	4.4	6161	5.9	341	5.3	3019	4.6	3072	4.5	2118	2.4	101	2.5
	2005	18,457	5.5	7331	7.0	418	6.5	4236	6.5	3511	5.1	2862	3.3	99	2.5
	2006	20,962	6.2	7016	6.7	382	5.9	5393	8.3	4066	6.0	3840	4.4	265	6.6
	2007	23,728	7.1	6905	6.6	546	8.5	5872	9.0	5113	7.5	4920	5.7	372	9.3
	2008	31,512	9.4	10,947	10.4	684	10.6	6578	10.1	6782	9.9	6146	7.1	375	9.4
	2009	27,590	8.2	8701	8.3	609	9.4	5624	8.6	6556	9.6	5698	6.6	402	10.1
	2010	37,769	11.2	10,485	10.0	816	12.7	7720	11.8	8417	12.3	9901	11.4	430	10.8
	2011	35,066	10.4	9286	8.8	625	9.7	6979	10.7	7175	10.5	10,500	12.1	501	12.5
	2012	47,586	14.2	13,144	12.5	719	11.1	6471	9.9	8772	12.9	17,920	20.7	560	14.0
	2013	49,332	14.7	13,620	12.9	652	10.1	6806	10.4	8792	12.9	18,781	21.7	681	17.1
Gender	male	148,978	44.4	47,616	45.3	3039	47.1	28,439	43.6	27,595	40.5	40,551	46.8	1738	43.5
	female	186,781	55.6	57,610	54.7	3411	52.9	36,760	56.4	40,581	59.5	46,164	53.2	2255	56.5
Age	0–7	65,998	19.8	24,042	22.8	1199	18.6	10,495	16.1	5137	7.5	24,692	28.5	433	10.8
	8–17	27,386	8.2	10,101	9.6	670	10.4	6399	9.8	4161	6.1	5820	6.7	235	5.9
	18–44	83,502	24.9	32,844	31.2	1432	22.2	17,797	27.3	13,314	19.5	17,333	20.0	782	19.6
	45–64	81,829	24.4	22,077	21.0	1526	23.7	15,207	23.3	19,151	28.1	22,463	25.9	1405	35.2
	65–	77,044	22.9	16,162	15.4	1623	25.2	15,301	23.5	26,413	38.7	16,407	18.9	1138	28.5

Table 3. Descriptive statistics of meteorological variables and air pollutants from 2002 to 2013 in Korea.

	All-Season					Warm Season (May to September)				
	N (Days)	Mean	SD	Min.	Max.	N (Days)	Mean	SD	Min.	Max.
Daily Mean Temperature (°C)	4383	12.7	9.4	−10.0	29.5	1836	21.8	3.5	11.4	29.5
Daily Maximum Temperature (°C)	4383	17.5	9.4	−6.0	34.5	1836	26.2	3.5	12.9	34.5
Daily Minimum Temperature (°C)	4383	8.3	9.9	−14.3	25.9	1836	18.0	4.3	4.6	25.9
Daily Relative Humidity (%)	4383	67.8	12.0	30.1	92.7	1836	74.9	9.3	39.5	92.7
Daily Mean Wind Speed	4383	2.0	0.7	0.7	7.2	1836	1.8	0.5	0.7	7.2
Daily Maximum Ozone (ppm)	4383	0.0	0.0	0.0	0.1	1836	0.0	0.0	0.0	0.1
Daily Mean PM10 (μg/m^3)	4383	55.1	32.2	11.7	653.4	1836	47.6	23.1	11.7	314.8

Table 4. Estimated relative risk of incidence for every 1 °C increase above 29.5 °C from May through September from 2002 to 2013.

		RR	**95% CI**		**lag 1**			**lag 2**			**lag 3**		
					RR	**95% CI**		**RR**	**95% CI**		**RR**	**95% CI**	
Total		**1.06**	1.06	1.06	**1.05**	1.05	1.06	**1.05**	1.05	1.05	**1.05**	1.05	1.05
Region	Region 1	**1.03**	1.03	1.03	**1.02**	1.02	1.02	**1.02**	1.02	1.02	**1.01**	1.01	1.02
	Region 2	**1.14**	1.13	1.15	**1.12**	1.12	1.13	**1.11**	1.11	1.12	**1.11**	1.10	1.11
	Region 3	**1.04**	1.04	1.04	**1.04**	1.03	1.04	**1.04**	1.03	1.04	**1.03**	1.03	1.03
	Region 4	**1.11**	1.10	1.11	**1.10**	1.10	1.10	**1.10**	1.09	1.10	**1.09**	1.09	1.09
	Region 5	**1.06**	1.05	1.06	**1.05**	1.05	1.05	**1.05**	1.04	1.05	**1.04**	1.04	1.05
	Region 6	**1.23**	1.21	1.25	**1.23**	1.21	1.25	**1.23**	1.21	1.24	**1.23**	1.21	1.25
Gender	male	**1.08**	1.08	1.08	**1.07**	1.07	1.07	**1.06**	1.06	1.06	**1.06**	1.05	1.06
	female	**1.05**	1.05	1.05	**1.04**	1.04	1.04	**1.04**	1.04	1.04	**1.04**	1.04	1.04
Age	0–7	**1.01**	1.01	1.01	0.99	0.99	1.00	**0.99**	0.99	0.99	**0.99**	0.98	0.99
	8–17	**1.04**	1.04	1.05	**1.03**	1.03	1.04	**1.03**	1.02	1.03	**1.02**	1.02	1.03
	18–44	**1.06**	1.06	1.06	**1.05**	1.05	1.05	**1.05**	1.05	1.05	**1.04**	1.04	1.05
	45–64	**1.09**	1.09	1.09	**1.09**	1.09	1.09	**1.09**	1.09	1.09	**1.08**	1.08	1.09
	65–	**1.08**	1.08	1.09	**1.08**	1.08	1.09	**1.08**	1.08	1.08	**1.08**	1.08	1.08

Note: lag 1; one day, lag 2; two days, lag 3; three days. Bold means statistically significant.

4. Discussion

This study demonstrated an increase in patients with heat related illnesses from 2002 to 2013 in Korea. This increase was identified in all regions and ages and both sexes when temperatures increased over 29.5 °C.

Several studies demonstrate a relationship between ambient temperature and heat related illnesses. During a 2003 heat wave in England, admission rates from emergency departments (ED) increased about 1% due to heat related illnesses, and there were 2091 excess deaths during this period (17%) [13]. In the summer months of 2006 in California, 16,166 (3%) excess visits to ED and 1.182 excess hospitalizations (1%) occurred. Patients with heat related illnesses visiting emergency departments during the at-risk period increased substantially (RR 6.3, 95% CI 5.67–7.01), and hospitalizations similarly increased (RR 10.15, 95%CI 7.79–13.43) [31]. A North Carolina study from 2007 to 2008 showed substantial increase in heat related illness as the temperature increased over 15 °C [32]. The current study confirms the increase in heat related illnesses as the temperature increases over 29.5 °C.

Due to their mental and physiologic immaturity, children are more vulnerable to environmental hazards including extremes in temperature [33]. We found a relatively lower risk in the youngest age group compared to adults and this finding is different from previous studies. In an Italian study, heat related illnesses were shown increased in those 14 or younger [34]. Similarly, a study from Brisbane, Australia demonstrated increased ED visits with increased temperatures [35]. Not only children are at increased risk of heat related illness, but also they utilize ED more frequently. In our study, the proportion of the children ages 0 to 7 years among the thermal illness patients is 19.8%, which is relatively higher than other age groups.

In addition, we showed increased risk of heat related illness in older patients. A 1995 Chicago study demonstrated a 35% increase in hospitalization during heat waves [14]. Increased mortality in those over 75 years of age was demonstrated in the 2003 London heat wave [13]. By checking the medical history of 726 patients over the age of 65 in the heat wave period in August 2003, France, 42 were thermal illness related patients and 12 (28.6%) died in the emergency room or after hospitalization [36]. In 2006 California, those over 65 years of age visited the ED 10.9 times more during the heat wave than days with normal temperatures [31].

5. Conclusions

In conclusion, the association between the daily maximum temperature and outbreaks of heat related illness has been identified. The number of patients with heat related illnesses increased annually and was especially noted in elderly and rural patients.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Korean Population Change, Maximum Temperature of the Year, and Number of Days above Threshold.

Year	Resident Population	Daily Maximum Temperature (°C)	Number of Days above Threshold (29.5 °C)
2002	48,125,745	36.6	22
2003	48,308,386	35.2	6
2004	48,485,314	37.9	31
2005	48,683,040	37.4	32

Table A1. *Cont.*

Year	Resident Population	Daily Maximum Temperature (°C)	Number of Days above Threshold (29.5 °C)
2006	48,887,027	37.2	26
2007	49,130,354	36.2	26
2008	49,404,648	37.7	32
2009	49,656,756	38.3	16
2010	49,879,812	37.0	35
2011	50,111,476	36.0	23
2012	50,345,325	38.3	31
2013	50,558,952	38.4	43

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