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Effect of Temperature Variation on the Incidence of Acute Myocardial Infarction

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ABSTRACT

Background: Harsh temperature exposure has been associated with a high risk of cardiovascular events. We sought to investigate the influence of temperature change on long-term incidence of acute myocardial infarction (AMI) in Korean patients.
Methods: From the National Health Insurance Service (NHIS) customized health information database (from 2005 to 2014), data from a total of 192,567 AMI patients was assessed according to the International Classification of Disease 10th edition code and matched with temperature reports obtained from the Korea Meteorological Administration database. We analyzed data for a 10-year period on a monthly and seasonal basis.
Results: The incidence rate per 100,000 year of AMI exhibited a downward trend from 69.1 to 56.1 over the period 2005 to 2014 ($P < 0.005$), and the seasonal AMI incidence rate per 100,000 year was highest in spring (63.1), and winter (61.3) followed by autumn (59.5) and summer (57.1). On a monthly basis, the AMI incidence rate per 100,000 year was highest during March (64.4) and December (63.9). The highest incidence of AMI occurred during temperature differences of 8–10° in each season. Moreover, AMI incidence tended to increase as the mean temperature decreased ($r = -0.233$, $P = 0.001$), and when the mean daily temperature difference increased ($r = 0.353$, $P < 0.001$).
Conclusion: The AMI incidence rate per 100,000 year has a decreasing trend over the 10-year period, derived from the Korean NHIS database. Modest daily temperature differences (8–10°) and the spring season are related to higher AMI incidence, indicating that daily temperature variation is more important than the mean daily temperature.

Keywords: Temperature; Acute Myocardial Infarction; Korean National Health Insurance Service

INTRODUCTION

In the contemporary era, a growing body of epidemiological and clinical evidence has led to heightened concern regarding the potential short- and long-term deleterious effects of climate change on cardiovascular health.[1] Acute myocardial infarction (AMI) is a major cause of disability and death worldwide, and can be triggered by meteorological and environmental factors, such as air temperature and microparticles.[2-4] Weather conditions have been shown to influence daily mortality and disease burden, especially in relation to the cardiovascular

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Conceptualization: Kim MH. Data curation: Lee KM, Jin CD, Kim MH. Formal analysis: Kim MH, Jin CD, Lee KM. Funding acquisition: Kim MH. Investigation: Kim MH, Jin CD, Lee KM. Methodology: Kim MH, Lee KM, Yun SC. Software: Lee KM. Validation: Kim MH, Jin CD. Visualization: Kim MH. Writing - original draft: Jin CD. Writing - review & editing: Kim MH, Jin CD.

system. Factors such as the extreme temperature, diurnal temperature range, temperature variation, and humidity have been considered as risk factors that may contribute to cardiovascular disease (CVD) mortality. In recent review of the literature showed that extreme (high or low) temperatures are associated with a higher risk of cardiovascular events.[5]

Assessing AMI events recorded in the National Registry of Myocardial Infarction, Spencer et al.,[6] suggested a seasonal pattern exists in the occurrence of AMI, characterized by a high risk of AMI cases in winter and a lower risk in summer months. In the East Asian (Japanese) AIM Registry, Rumana et al.,[7] reported that seasonal variations in case occurrence and AMI case fatalities peaked in winter and spring. However, additional findings from research on ambient temperature and cardiovascular events have been inconsistent.[8-12] Here, we investigated the impact of temperature on the incidence of AMI in the Korean population using the National Health Insurance Service (NHIS) database and weather information from the Korea Meteorological Administration.

METHODS

Study setting and population

This observational and ecological study sought to investigate the impact of air temperature on the incidence of AMI over a 10-year period from January 2005 to December 2014. The study population included residents in the Republic of Korea, with a permanent resident population of around 50 million.

Data collection

Monthly AMI data were extracted from the Korean NHIS database according to the International Classification of Disease 10th edition (ICD-10) A total of 192,567 AMI cases were extracted without district-specific data available. In this study, new-onset acute myocardial infarction was defined as follows: First, patients must have no ICD-10 code for acute myocardial infarction or have not undergone percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) in 2004. Next, these patients are those who were hospitalized with an ICD-10 code or underwent PCI or CABG since 2005. Daily temperature (°C) data was systematically collected from the Korea Meteorological Administration Research database. Over a 10-year period, we assessed the data over 3 phases, including early (from 2005 to 2007), middle (from 2008 to 2010), and late (from 2011 to 2014) phase. Seasonal categories were as follows: spring (March, April, May), summer (June, July, August), fall (September, October, November), and winter (December, January, February).

Statistical analysis

We used an indirect standardization method for the age-gender standardized incidence of AMI. The age-sex standardized incidence method was as follows: After dividing by gender, age standardization was performed. Age standardization adjusted for differences between groups of various ages to make them comparable. For standardization purposes, a specific reference age is usually chosen and data from other age groups are adjusted to this reference. Descriptive statistical methods were used to describe the characteristics of the variables. Monthly incidence of AMI and mean temperature were examined graphically using time-series plots. Statistical analyses were performed using IBM SPSS version 22 (IBM Corp., Armonk, NY, USA). Pearson's correlation coefficient was performed to assess the relationship between temperature and AMI. A two-tailed *P* value of < 0.05 was the criteria for statistical significance. Statistical graphing was performed using Excel software.

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Ethics statement

The study protocol was approved by the Institutional Ethics Committee of Dong-A University Hospital (IEC-DAUH 15-130) and classified as minimal-risk research using anonymized data collected for routine clinical practice. The requirement for informed consent was waived.

RESULTS

Study population, annual AMI rate distribution and temperature

A total of 192,567 AMI cases (mean age: 64 years) were recorded in the Korean NHIS database. They were predominantly male (67.4, n =129,846, mean age: 61 ± 13 years), with males generally younger than female (difference in mean age of 11 years). Classifying according to age range, the majority of the population was middle-aged and older adults (40–59 years, > 60 years) for males, whereas older adults (> 60 years) were more likely to be female (**Table 1**). The distribution in monthly and annual incidence of AMI from 2005 to 2014 (**Table 2**) showed, that the mean AMI incidence rate per 100,000 year was 63.3. Over

Table 1. The demographics in Korean patients with AMI

Age classification	Overall (N = 192,567)	Male (n = 129,846)	Female (n = 62,721)
Age, yr	64 ± 13	61 ± 13	72 ± 11
< 40	6,145 (3.2)	5,641 (4.3)	504 (0.8)
40–49	23,536 (12.2)	21,437 (16.5)	2,099 (3.4)
50–59	41,643 (21.6)	35,741 (27.5)	5,902 (9.4)
60–69	46,703 (24.3)	32,834 (25.3)	13,869 (22.1)
70–79	49,169 (25.5)	25,218 (19.4)	23,951 (38.2)
≥ 80	25,371 (13.2)	8,975 (6.9)	16,396 (26.1)

Values are presented as mean ± standard deviation or number (%).
AMI = acute myocardial infarction.

Table 2. The distribution in monthly incidence of AMI from 2005 to 2014 in Korean

Month	AMI	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
1	No.	1,513	1,772	1,722	1,621	1,592	1,461	1,510	1,796	1,685	1,786	16,458
	IR	66.4	70.7	68.9	66.5	60.6	55.9	56.8	63.3	56.8	55.5	62.1
2	No.	1,338	1,542	1,570	1,569	1,506	1,400	1,497	1,648	1,622	1,762	15,454
	IR	58.8	65.4	60.5	64.1	56.8	52.0	54.3	56.6	53.4	58.4	58.0
3	No.	1,589	1,831	1,781	1,743	1,593	1,620	1,576	1,728	1,893	1,873	17,227
	IR	69.0	73.5	71.1	69.8	60.7	59.5	57.2	61.3	63.6	58.7	64.4
4	No.	1,515	1,633	1,736	1,603	1,567	1,538	1,541	1,659	1,701	1,883	16,376
	IR	67.9	69.1	69.4	67.4	60.5	56.5	56.0	57.4	58.4	60.7	62.3
5	No.	1,501	1,656	1,764	1,560	1,615	1,571	1,594	1,618	1,788	1,794	16,461
	IR	63.4	71.0	73.0	61.5	66.4	59.6	58.1	56.4	59.0	57.9	62.6
6	No.	1,392	1,561	1,638	1,406	1,514	1,422	1,502	1,461	1,643	1,735	15,274
	IR	61.9	63.5	65.0	56.0	58.9	53.9	54.7	48.3	54.7	55.1	57.2
7	No.	1,333	1,554	1,592	1,405	1,471	1,468	1,528	1,542	1,660	1,806	15,359
	IR	59.7	66.8	65.8	55.1	56.4	54.4	53.4	53.8	53.4	57.1	57.6
8	No.	1,438	1,664	1,494	1,417	1,479	1,447	1,557	1,522	1,625	1,717	15,360
	IR	59.0	69.4	59.0	54.6	55.3	54.9	54.4	51.8	54.2	52.5	56.5
9	No.	1,425	1,557	1,494	1,486	1,507	1,457	1,424	1,527	1,669	1,823	15,369
	IR	59.2	68.3	60.6	58.7	57.4	52.6	49.0	52.6	53.6	60.2	57.2
10	No.	1,594	1,616	1,642	1,543	1,541	1,506	1,635	1,744	1,702	1,827	16,350
	IR	65.3	70.0	67.3	60.2	58.5	55.5	57.1	60.5	57.2	58.7	61.0
11	No.	1,581	1,663	1,545	1,466	1,375	1,586	1,605	1,593	1,756	1,795	15,965
	IR	67.4	69.3	67.2	59.3	51.5	57.4	59.2	53.6	58.7	59.1	60.3
12	No.	1,718	1,752	1,641	1,570	1,499	1,586	1,687	1,672	1,820	1,969	16,914
	IR	74.5	72.6	67.0	62.8	56.5	60.1	63.1	58.0	59.7	64.6	63.9
Total	No.	17,937	19,801	19,619	18,389	18,259	18,062	18,656	19,510	20,564	21,770	192,567
	IR	64.4	69.1	66.2	61.3	58.3	56.0	56.1	56.1	56.9	58.2	60.3

AMI = acute myocardial infarction, IR = incidence rate per 100,000 year.

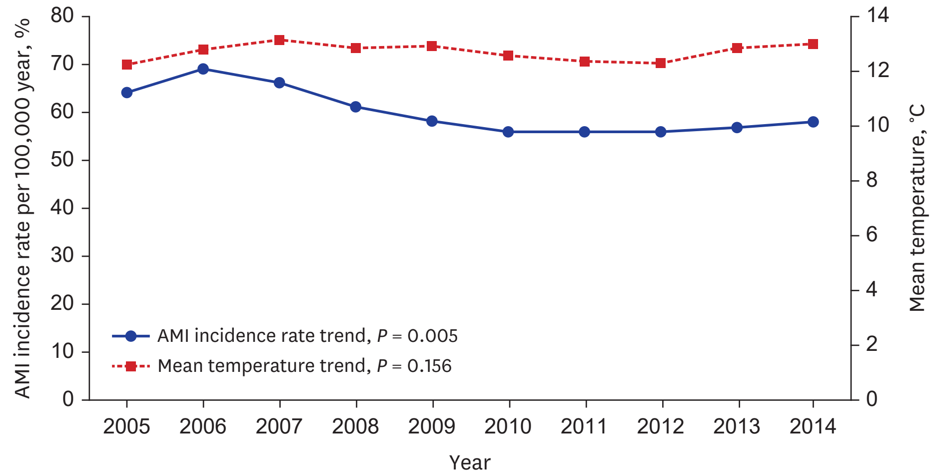

Fig. 1. Temporal trend in the occurrence of AMI, and distribution of annual incidence of AMI and mean temperature from 2005 to 2014.
AMI = acute myocardial infarction.

the 10-year period, there was a decreasing tendency (69.1 down to 56.1, P for trend 0.005) in prevalence of AMI from 2005 to 2014 (**Fig. 1**).

Effects of mean temperature monthly AMI incidence

The distribution of monthly incidence of AMI according to temperature change is shown in the **Supplementary Fig. 1**. Overall, with the mean temperature decreasing from September, the incidence of AMI was getting increasing. In contrast, with the weather getting warmer in summer (June, July and August) the AMI incidence is decreasing. The highest monthly incidence of AMI was March, followed by December (**Supplementary Fig. 1**).

Effect of mean daily temperature change, seasonal variation and incidence of AMI

The distribution of AMI events according to daily temperature change is shown in **Fig. 2**. There was a moderate negative linear relationship between mean temperature and monthly AMI occurrence ($r = -0.233$, $P = 0.001$) (**Fig. 3A**). The highest incidence of AMI occurred at a temperature difference of 8–10° (**Fig. 2A**), with a moderate positive linear relationship ($r = 0.353$, $P < 0.001$) (**Fig. 3B**). In the distribution of seasonal AMI events, the incidence rate per 100,000 year was higher during the colder seasons (63.1 in spring, and 61.3 in winter), followed 59.5 in the fall and 57.1 in summer (**Fig. 2B**).

DISCUSSION

According to the NHIS-derived AMI Registry from 2005 to 2014 in the Republic of Korea, we report that temperature change (cold) has an adverse impact on the occurrence of AMI. Daily temperature differences share a liner correlation with increasing AMI events, with the same being evident for increasing daily temperature differences. The triggers for AMI have been examined in several studies, and among the factors associated with the onset of AMI, intense exercise or physical exertion, diet, coffee and alcohol consumption, smoking, sexual activity, cocaine or marijuana abuse, emotional stress and environmental conditions have been reported.[13] Environmental conditions most often refer to temperature, air pollution

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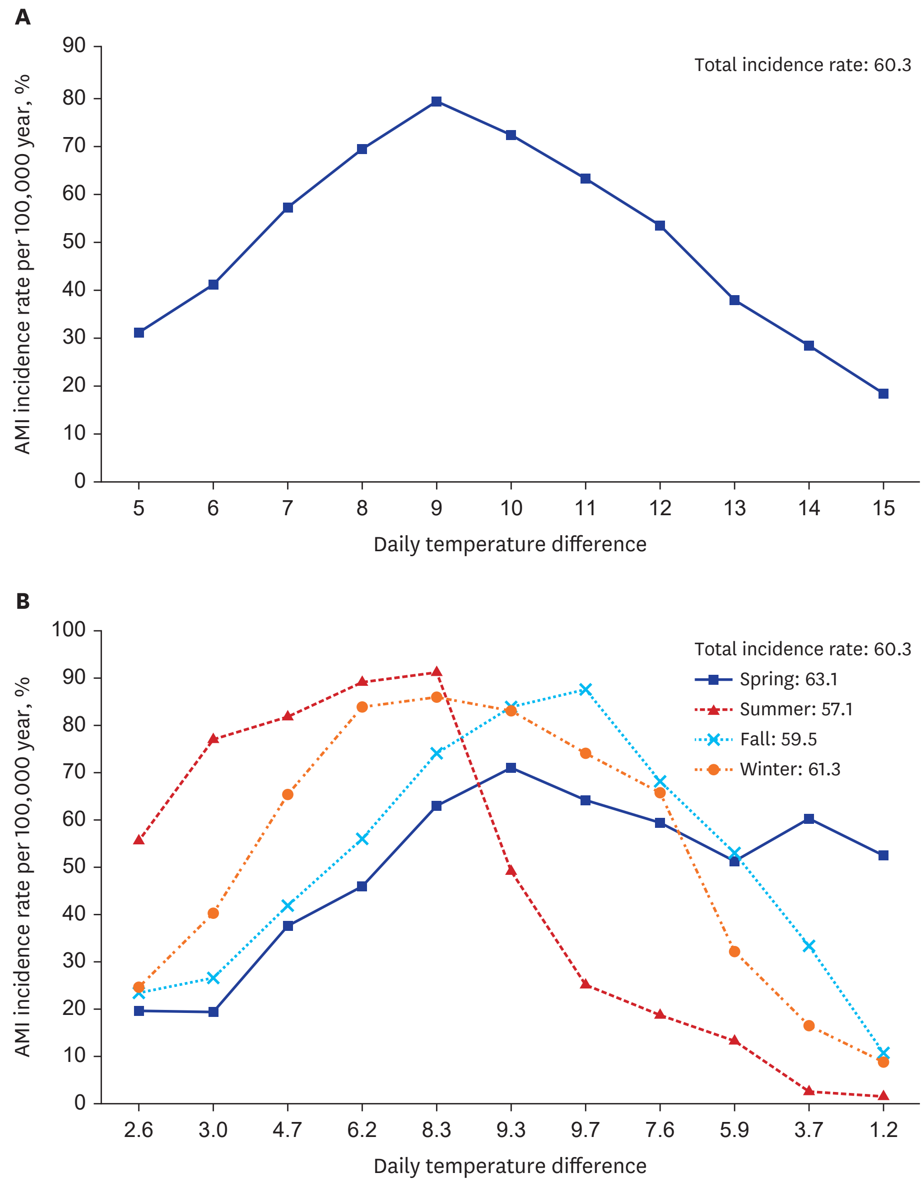

Fig. 2. The distribution of (**A**) overall AMI events and (**B**) seasonal AMI events according to daily temperature difference. Spring: March, April, May; Summer: June, July, August; Fall: September, October, November; Winter: December, January, February.
AMI = acute myocardial infarction.

and influenza epidemics.[14] Here, we focused on temperature change and AMI events in the context of global warming, with an increase in mean temperatures of about 0.8°C occurring over the last 20 years in the Republic of Korea.

Cold weather can cause rises in catecholamine levels and subsequent vasoconstriction, increasing heart rate and blood pressure, which may precipitate myocardial ischemia and coronary plaque instability.[2] We observed that the incidence of AMI was relatively lower in summer (June, July, and August), and the event rate increased as temperatures declined from September to April and when daily temperature differences were greater, such as during spring, with a slight decrease in incidence during the extreme cold season with smaller daily

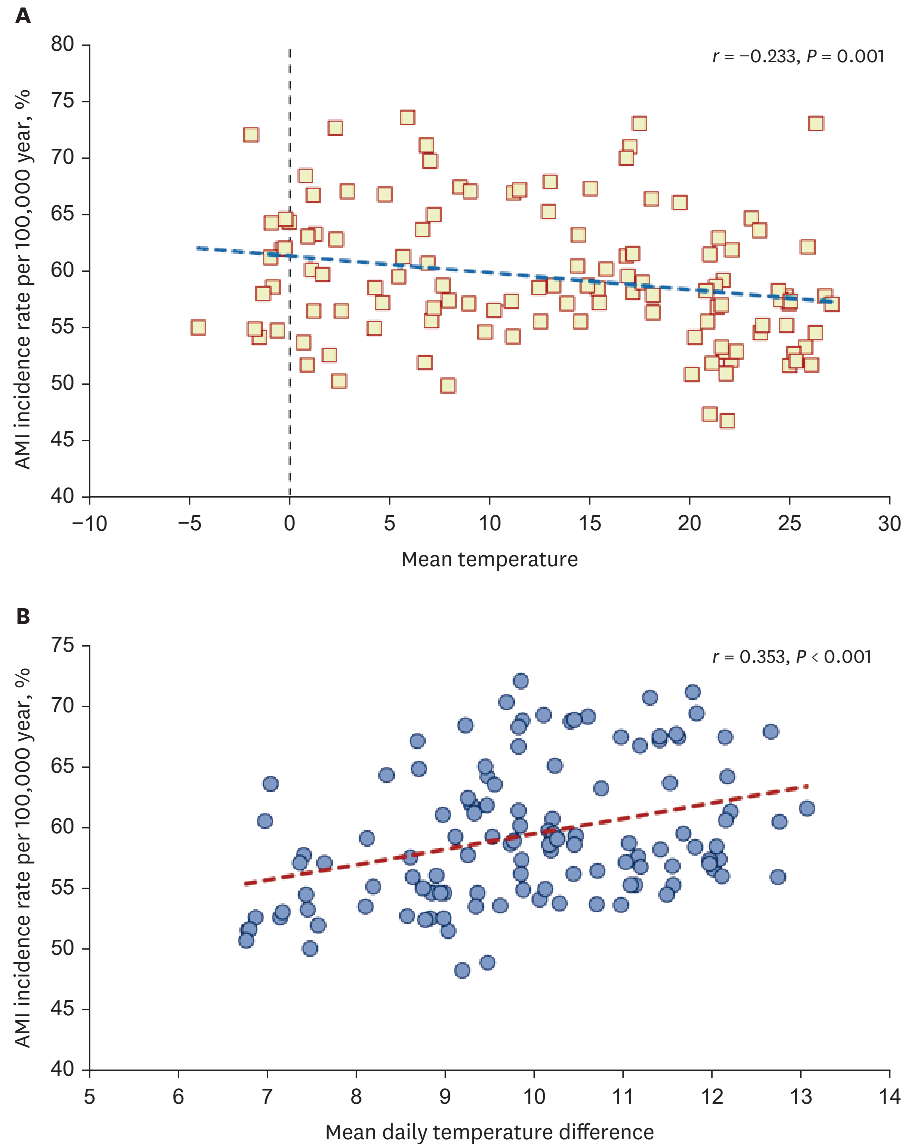

Fig. 3. Relationship between AMI incidence and mean temperature (**A**), mean daily temperature difference (**B**).
AMI = acute myocardial infarction.

temperature differences (January and February). We also identified a moderate negative relationship between mean temperature and monthly occurrence of AMI. Consistent with previous findings, temperature decreases were associated with higher frequency of AMI occurrence.[15,16] This finding was consistent with warmer areas of tropical or subtropical regions such as Taiwan and Singapore.[17,18]

In a previous study of the Korean AMI Registry from 1997–2006, Hong and Kang[19] investigated the relationship between seasonal variation and AMI mortality in Korean patients using the Korean National Health Insurance Claims Database. The results showed a winter peak and summer nadir. In the general trend, there was a decrease in occurrence of annual AMI events from the early (0.066%) to middle (0.058%) phase, being lowest in the late (0.057%) phase, which may be hypothetically explained by global warming-related declines in acute cardiovascular events. During unseasonably cold days, the majority of the population a places

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a priority on keeping warm and reduces out-door physical activity. This may reduce the overall levels of physical exertion, causing a subsequent reduction in AMI occurrence, which may explain, in part, the findings for the coldest months (January and February). As well as global warming, less smoking, warmer housing conditions and less outside work with regard to the economic growth of Korea may have reduced AMI events during the winter season. Interestingly, modest temperature changes (8–10 degrees) correlate with the highest AMI incidence. This difference was a slightly lower than previously reported mean temperature differences of 10.3 to 12.7 degrees, which might be related to temperature zone differences.[2] With such modest temperature differences, people participating in more outdoor activities or exercise might have an increased risk of AMI.[20,21] Therefore, not only cold temperature, but also transitions and variability of temperature may be more important to trigger AMI.[22-24]

We note several limitations to our study. Firstly, important information for the analyzed population regarding AMI incidence including risk factors and medications was not included. Secondly, data was limited in relation to meteorological conditions such as air pressure,[25] cloudy and rainy days with high humidity, and long sunshine duration,[26] which have also been associated with cardiovascular events. In the fall and winter periods, a higher incidence of hospital admissions has been noted due to cardiopulmonary diseases related to atmospheric stagnation.[27] Thirdly, cold weather also contributes to ambient air pollution. Chen et al.,[28] reported that even short-term, transient (i.e., Several hours) exposure to air pollution can trigger the onset of AMI. Data for typical air pollutants including PM2.5, nitrogen dioxide, and sulfur dioxide were not extracted from the National Institute of Environmental Research database. Finally, there may be a potential bias from extracting our data or ICD-10 code from the NHIS database.

In conclusion, from the Korean NHIS database, the AMI event rate has a decreasing trend over the 10-year period. Modest daily temperature differences (8–10°) and the spring season correlate with higher AMI incidence, indicating daily temperature variation is more important than the mean daily temperature.

SUPPLEMENTARY MATERIAL

Supplementary Fig. 1

Monthly incidence of AMI according to temperature variation from 2005 to 2014. (**A**) January to December and (**B**) July to June.

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