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Effects of Atmospheric Temperature and Pressure on the Occurrence of Acute Myocardial Infarction in Hiroshima City, Japan

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ABSTRACT

In contrast to studies of the effects of atmospheric temperature and pressure on the occurrence of acute myocardial infarction (AMI), the interaction of these two factors has rarely been studied. We analyzed ambulance data (1993–2002) due to AMI in Hiroshima City using the poisson regression model to examine the main effects and the interaction of atmospheric temperature and pressure on AMI (n=3755). In the analysis, thermohydrological-index (THI), or humidity adjusted temperature, was calculated to involve the effect of relative humidity. The significant influence of atmospheric temperature on AMI was confirmed. Daily events of AMI decreased as temperature increased. Daily events in the low, moderate, and high temperature groups were 1.16, 1.07 and 0.90, respectively (average=1.03/day). Atmospheric pressure showed a weaker effect in the presence of temperature. A more profound interaction was found between temperature and pressure. The highest daily events 1.38 were observed in the low temperature and low pressure group, while this meteorological type was always accompanied by rain and/or snow. It was significant (p=0.047) and 37% higher than that of the high temperature and moderate pressure group. The lowest daily events 0.87 were observed in the high temperature and low pressure group. These associations were reinforced when temperature adjusted by relative humidity was used. Atmospheric temperature and the interaction of temperature and pressure had significant influences on the occurrence of AMI. The highest risk was found on days with low temperature and low pressure. Days with high risk were characterized by winter rain and/or snow.

Key words: *Myocardial infarction, Atmospheric temperature, Atmospheric pressure*

The influence of meteorological factors on the occurrence of acute myocardial infarction (AMI) has impressed many clinicians. AMI exhibits a winter peak and summer trough in incidence and mortality[24,25)]. The higher winter rate of cardiac events has been demonstrated in both the northern and southern hemispheres[2,5,12,18-20,23,27)]. Although it has been recognized that cold temperature acts as a trigger for coronary events[22)], some studies show that both low and high temperatures cause an increase in coronary heart disease[8,17)].

Meteorological factors, other than atmospheric temperature, have rarely been studied. Atmospheric pressure is regarded as one of the meteorological factors affecting cardiovascular mortality and morbidity. To the best of our knowledge, only a few studies have referred to the impact of atmospheric pressure on AMI[6,21)], but these results lacked consistency, and no studies have reported the interaction of atmospheric temperature and pressure.

The influence of meteorological factors on AMI might not be universal in different geographic areas. Exploring the influence of meteorological factors on AMI has an important significance in public health, especially in Japan, where complicated variations of atmospheric temperature and pressure are observed.

The aim of this study was to clarify the impact of atmospheric temperature, pressure, and their interaction on the occurrence of AMI. We performed this population-based study by analyzing 10 year data of 3755 AMI events from 1993 to 2002.

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MATERIALS AND METHODS

Study area

Hiroshima City is located in southwest Japan (longitude, from 132°18'34" to 132°41'48" east; latitude, from 34°17'37" to 34°36'41" north), with a population of 1,126,239. The city faces the Seto Inland Sea to the south, and is surrounded by mountains about 600–1000 meters above sea level in the other three directions. It extends approximately 35 km from east to west and north to south, and has an area of 741.6 km^2 (as of 2000).

Located in the Seto Inland Climate Zone, Hiroshima City has a temperate monsoon climate with relatively low rainfall in Japan. Since the monsoon from the south in summer and from the north in winter is often blocked by mountains, it enjoys a warm and comfortable climate throughout the year. Average atmospheric temperature, pressure, and relative humidity (Mean ± SD) during the 10 year period was 16.5 ± 8.3°C (range: –0.9–32.7°C), 1008.9 ± 6.7 hPa (range: 986.0–1029.4 hPa) and 68.1 ± 10.7% (range: 31.0–99.0%), respectively.

Meteorological data

Meteorological data was obtained from The Japan Meteorological Agency. The meteorological variables included atmospheric temperature, pressure, relative humidity, rain, and snowfall.

Acute Myocardial Infarction Data

In order to predict AMI events by using meteorological factors, The Myocardial Infarction Predicting Committee, consisting of Hiroshima University, Hiroshima City Medical Association, Hiroshima City Fire and Ambulance Department and Hiroshima Weather Association Chugoku Branch, was established. AMI data used in the analysis was collected by Hiroshima Ambulance Service Center during 1993–2002.

The data we used in the analyses is based on the record of patients carried by ambulance. For ethical considerations, personal information was not included and completely anonymous data was used. Diagnosis of AMI for each patient was given by physicians in emergency hospitals. In the diagnosing process, the data of electrocardiogram and/or enzyme in blood samples were used in addition to symptoms for some patients, but not for all. The criteria are based on the clinical judgment of physicians and may not be exactly uniform. An assessment of data quality is described below.

In the record of patients carried by ambulance, heart disease was classified into: angina pectoris, myocardial infarction, heart attack and heart failure. They comprised 35%, 28%, 3% and 34% in 2000 (Hiroshima City Fire and Ambulance Department, personal communication), respectively. Myocardial infarction was discriminated from angina pectoris, although more than one third was classified as heart failure. To clarify the coverage of ambulance data against total myocardial infarction in Hiroshima City, the expected numbers of myocardial infarction were calculated based on the age-specific incidence data of AMI reported by Yoshida et al[31)] in Shiga and Kinjo et al[11)] in Okinawa, Japan. Using population data in Hiroshima City in 2000, the results were 442 (294 male and 148 female) and 451 (304 male and 147 female), respectively. The observed numbers of ambulance data in 2000 were 361 (242 male and 119 female). Approximately 80% of myocardial infarction in Hiroshima City seemed included in our data. Viewing the estimated and observed numbers by sex and age, they showed quite a similar pattern. We thus concluded that the ambulance myocardial infarction data were valid for the analysis of risk factors.

Statistical analysis

Statistical analysis was performed using SPSS 12.0 J (SPSS Institute Inc. Chicago, IL). Average daily events were plotted according to 1°C daily mean atmospheric temperature and 1 hPa atmospheric pressure variations. The occurrence of AMI events was perfectly consistent with theoretical poisson distribution[26)], thus we fitted our data with the poisson regression model to determine the association between daily events and meteorological variables.

Daily mean atmospheric temperature and pressure were divided into three groups; the cut-off points were selected so that group size was nearly the same. The definition of the groups is as follows: low temperature (T1: $T<10$°C), moderate temperature (T2: $10\leq T<20$°C), and high temperature (T3: $T\geq 20$°C); low pressure (P1: $P\leq 1005$ hPa), moderate pressure (P2: $1005<P\leq 1012$ hPa), and high pressure (P3: $P>1012$ hPa). We obtained nine meteorological groups according to the different atmospheric temperatures and pressures. Thermohydrological-index was employed to calculate humidity adjusted temperature (THI). The mathematical formula is

$$THI=T_a - 0.55 \times (1 - 0.01RH) \times (T_a - 14.5)$$

where T_a=Daily mean atmospheric temperature (Celsius), and RH=Daily mean relative humidity in percent. This index has been suggested as an appropriate measure for the evaluation of the effect of air temperature on health outcomes, since low or high temperature is adjusted to be milder if relative humidity is low[18)].

RESULTS

During this 10 year period, 3755 AMI events occurred (average 1.03 events per day). The range of annual events was from 344 to 402 (Mean ± SD: 376 ± 17). There was a linear decreasing relationship between average daily events and daily mean atmospheric temperature. Average daily events were all lower than the 10 year average level when atmospheric temperature was higher than 18°C. The same relationship also existed when atmospheric temperature was adjusted by relative humidity, even though the temperature range changed from –0.9–32.7°C to 1.3–28.2°C (Fig. 1).

There was an increasing linear relationship between average daily events and daily mean atmospheric pressure. The linear relationship was only clearly observed from 993 to 1015 hPa, while deviation was large at both ends due to the small sample size. Average daily events were higher than the 10 year average level when atmospheric pressure increased above 1010 hPa (Fig. 2).

Atmospheric temperature showed significant main effects on the occurrence of AMI. Daily events for the low, moderate, and high temperature groups were 1.16, 1.07 and 0.90, respectively. Compared to the high temperature group, daily events for the low and moderate temperature groups increased by 17% (p=0.037) and 12% (p=0.079), respectively. Interactions between atmospheric temperature and pressure were found in the low and high temperature groups. In these two temperature groups, daily events varied for different pressure groups. The highest daily events were 1.38 which occurred in the low temperature and low pressure group, and 37% higher compared with the high temperature and moderate pressure group. The lowest daily events were observed in the high temperature and low pressure group, with 0.87 events per day (Table 1). The above associations are strengthened when atmospheric temperature is adjusted by relative humidity (Table 2).

The most dangerous days for AMI, which occurred in the low temperature and low pressure group (T1P1), were characterized by lower temperature, lower pressure, and highest relative humidity (days with rain were 100%; days with rain and snow together were 25%). There were only 40 days of this type during the 10 year period, and all occurred in winter or early spring (Jan: 11 days; Feb: 15 days; Mar: 14 days). The second worse days (T1P3) with the lowest temperature and the highest pressure, happened in winter, spring and late autumn; these days were characteristic of a cold and dry climate. The worst days for AMI were also found in the high temperature and high pressure group (T3P3). This type was characteristic of a hot and dry climate, with the lowest relative humidity, and the lowest percentage of days with rain. The safest days were found in the high temperature and low pressure group (T3P1); these days were characteristic of a hot and wet climate and were distributed in summer, early autumn, and late spring (Table 3, Fig. 3).

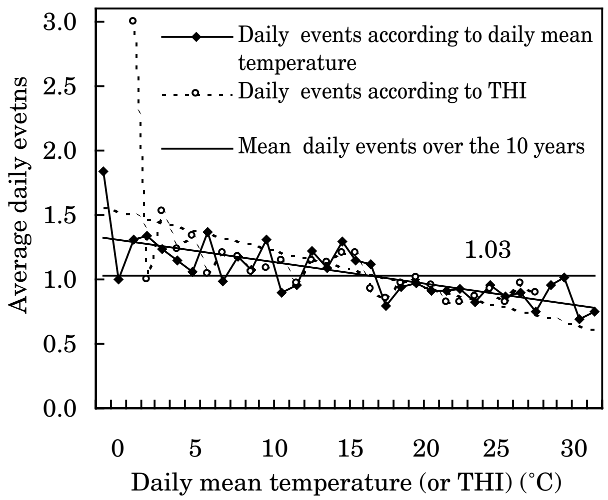

Fig. 1. Average daily events of AMI versus daily mean atmospheric temperature or humidity adjusted temperature (THI). The x-axis represents daily mean atmospheric temperature and humidity adjusted temperature (THI), respectively. Slanting dashed and solid lines show average daily events predicted by regression model. A linear decreasing relationship is shown between average daily events and daily mean atmospheric temperature (or THI). Average daily events were all lower than the 10 year average level (1.03/day) when atmospheric temperature was higher than 18°C.

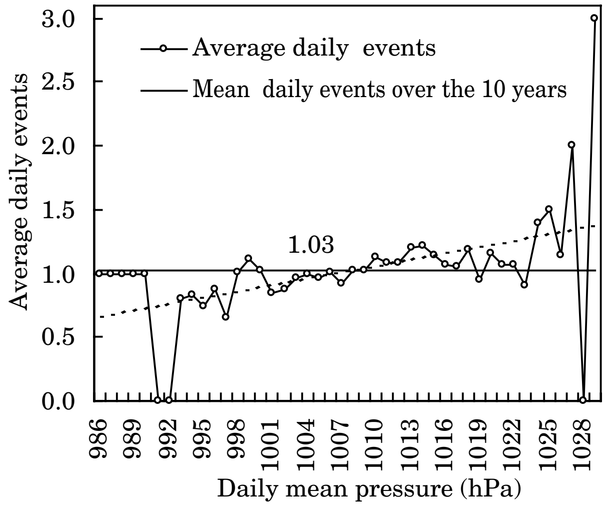

Fig. 2. Average daily events of AMI versus daily mean atmospheric pressure. Dashed line shows average daily events predicted by regression model. There is an increasing linear relationship between average daily events and daily mean atmospheric pressure (at the range of 993–1015 hPa). Average daily events were higher than the 10 year average level when atmospheric pressure increased above 1010 hPa.

Table 1. AMI events and parameters estimated from poission regression model by atmospheric temperature and pressure

	β-coefficient ± S.E.	RR (95%CI)	p	Total events	Number of days	Daily events
Daily mean atmospheric temperature (˚C)						
T1	0.15 ± 0.07	1.17 (1.01 1.35)	0.037*	1266	1096	1.16
T2	0.11 ± 0.06	1.12 (0.99 1.27)	0.079	1190	1117	1.07
T3	reference			1299	1439	0.90
Daily mean atmospheric pressure (hPa)						
P1	–0.08 ± 0.06	0.92 (0.82 1.03)	0.161	1038	1118	0.93
P2	reference			1276	1252	1.02
P3	0.09 ± 0.14	1.09 (0.82 1.44)	0.556	1441	1282	1.12
Interaction of atmospheric temperature and pressure						
T1 * P1	0.31 ± 0.16	1.37 (1.00 1.86)	0.047*	55	40	1.38
T1 * P2	reference			297	270	1.10
T1 * P3	–0.03 ± 0.16	0.97 (0.71 1.32)	0.848	914	786	1.16
T2 * P1	0.11 ± 0.10	1.11 (0.92 1.35)	0.287	228	211	1.08
T2 * P2	reference			488	462	1.06
T2 * P3	–0.07 ± 0.16	0.93 (0.68 1.27)	0.638	474	444	1.07
T3 * P1	reference			755	867	0.87
T3 * P2	reference			491	520	0.94
T3 * P3	reference			53	52	1.02

T1: Low temperature T2: Moderate temperature T3: High temperature
P1: Low pressure P2: Moderate pressure P3: High pressure *: $p < 0.05$
Reference: The high temperature and moderate pressure group
RR: Daily events compared with the reference group

Table 2. AMI events and parameters estimated from poission regression model by humidity adjusted temperature (THI) and pressure

	β-coefficient ± S.E.	RR (95%CI)	p	Total events	Number of days	Daily events
Humidity adjusted temperature (THI) (˚C)						
THI1	0.20 ± 0.08	1.22 (1.04 1.42)	0.014*	1099	943	1.17
THI2	0.11 ± 0.06	1.11 (0.98 1.26)	0.095	1552	1448	1.05
THI3	reference			1134	1261	0.90
Daily mean atmospheric pressure (hPa)						
P1	–0.07 ± 0.06	0.93 (0.82 1.05)	0.239	1038	1118	0.93
P2	reference			1276	1252	1.02
P3	0.32 ± 0.17	1.37 (0.99 1.91)	0.060	1441	1282	1.12
Interaction of THI and pressure						
THI1 * P1	0.37 ± 0.16	1.45 (1.05 1.99)	0.023*	53	35	1.51
THI1 * P2	reference			254	224	1.13
THI1 * P3	–0.30 ± 0.18	0.74 (0.52 1.06)	0.104	792	684	1.16
THI2 * P1	0.06 ± 0.10	1.07 (0.87 1.28)	0.496	293	285	1.03
THI2 * P2	reference			618	595	1.04
THI2 * P3	–0.28 ± 0.18	0.75 (0.53 1.07)	0.113	611	568	1.08
THI3 * P1	reference			692	798	0.87
THI3 * P2	reference			404	433	0.93
THI3 * P3	reference			38	30	1.27

THI1: Low temperature ($THI<10$°C) THI2: Moderate temperature ($10\leq THI<20$°C)
THI3: High temperature ($THI\geq 20$°C) *: $p< 0.05$
Reference: The high temperature and moderate pressure group
RR: Daily events compared with the reference group

DISCUSSION

This is the first study to clarify the impact of the interaction between atmospheric temperature and pressure, in addition to the main effects of these two factors on the occurrence of AMI. Our study showed that it was not only atmospheric temperature, but also the interaction of atmospheric temperature and pressure that influenced the occurrence of AMI.

Table 3. Seasonal distribution for the different meteorological type groups

	Mean temperature (˚C)	Mean pressure (hPa)	Number of days	Seasonal distribution			
				Winter	Spring	Summer	Autumn
Low temperature (T1, T<10˚C)							
T1P1	6.8 ± 2.5	1002.6 ± 2.6	40 (100)	26 (65.0)	14 (35.0)	0 (0.0)	0 (0.0)
T1P2	6.8 ± 2.2	1009.3 ± 1.9	270 (100)	192 (71.1)	59 (21.9)	0 (0.0)	19 (7.0)
T1P3	6.3 ± 2.1	1016.7 ± 3.2	786 (100)	600 (76.3)	132 (16.8)	0 (0.0)	54 (6.9)
T1	6.5 ± 2.2	1014.4 ± 4.9	1096 (100)	818 (74.6)	205 (18.7)	0 (0.0)	73 (6.7)
Moderate temperature (T2, 10≤T<20˚C)							
T2P1	16.2 ± 2.8	1001.9 ± 2.5	211 (100)	9 (4.3)	170 (80.6)	9 (4.3)	23 (10.9)
T2P2	15.5 ± 3.0	1008.8 ± 2.0	462 (100)	37 (8.0)	265 (57.4)	4 (0.9)	156 (33.8)
T2P3	14.3 ± 2.9	1015.5 ± 2.7	444 (100)	38 (8.6)	132 (29.7)	0 (0.0)	274 (61.7)
T2	15.2 ± 3.0	1010.2 ± 5.5	1117 (100)	84 (7.5)	567 (50.8)	13 (1.2)	453 (40.5)
High temperature (T3, T≥20˚C)							
T3P1	25.6 ± 3.0	1001.1 ± 3.2	867 (100)	0 (0.0)	67 (7.7)	655 (75.6)	145 (16.7)
T3P2	25.1 ± 3.4	1007.4 ± 1.7	520 (100)	0 (0.0)	71 (13.6)	252 (48.5)	197 (37.9)
T3P3	21.7 ± 1.5	1014.0 ± 1.6	52 (100)	0 (0.0)	10 (19.2)	0 (0.0)	42 (80.8)
T3	25.2 ± 3.2	1003.8 ± 4.5	1439 (100)	0 (0.0)	148 (10.3)	907 (63.0)	384 (26.7)

Number in parentheses is the percentage of days in each meteorological type group (%)
Winter: (Dec Jan Feb) Spring: (Mar Apr May) Summer: (Jun Jul Aug) Autumn: (Sep Oct Nov)

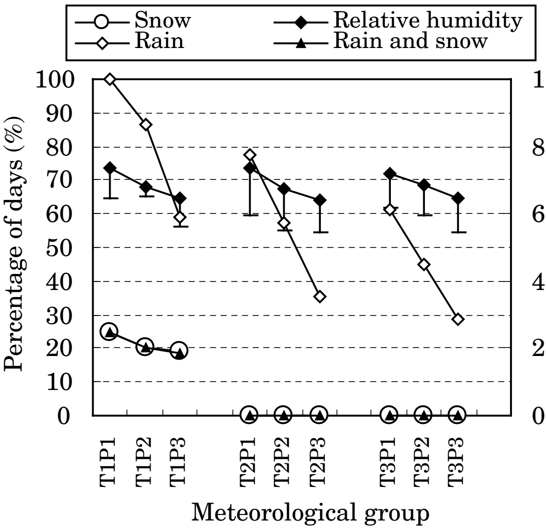

Fig. 3. Relative humidity and percentage of days with rain and/or snow for different meteorological groups (Relative humidity is shown as Mean-SD). The most dangerous days for AMI (T1P1, the low temperature and low pressure group) were with the highest relative humidity, days with rain were 100%, and days with rain and snow together were 25%.

Atmospheric temperature independently influenced AMI events. Daily events of AMI were higher at low temperatures, and decreased with atmospheric temperature linearly. Poisson regression analysis revealed a dose response relationship existing in the low, moderate, and high temperature groups. Our findings support the results of studies from countries with various climates, demonstrating that low temperature was related to the winter peak of AMI mortality, and an increase in hospital admission rate[2,5,12,18,20,22-25,27] Several studies reported a U-shaped or V-shaped relationship, indicating that both low and high temperatures increase AMI mortality[8,17]. We did not observe any independent bad effects of high temperature. One reason for this might be that our study was based on occurrence data, rather than mortality data in which fatal cases tend to be easily affected by atmospheric temperature. Another reason might be that the atmospheric temperature in Hiroshima City was not high enough to show an obvious harmful effect on the heart. We found that daily events were all lower than the 10 year average as daily mean atmospheric temperature increased from 18˚C, and the lowest daily events were at 28˚C (0.75 events per day), except for small sample points located at both ends. This result is consistent with Pan et al[17], who noted that the lowest AMI mortality happened on days with a daily mean atmospheric temperature from 26 to 29˚C. Huynen et al[8] found the optimum temperature to be 16.5˚C for cardiovascular mortality.

Temperature was generally accepted as one of the environmental risk factors that influence the occurrence and mortality of AMI. Low temperature may exert a direct effect on the heart, or has an indirect effect via changes in blood pressure. One study reported that prolonged differences in the usual diastolic blood pressure of 5, 7.5, and 10 mmHg, were associated with at least 21%, 29% and 37% less coronary heart disease incidence, respectively[14]. Environmental temperatures have a negative linear correlation with blood pressure[13]. In Britain, winter blood pressure exceeds summer pressure by around 5 mmHg[29]; raised blood pressure in cold temperatures has been reported in many studies[1,4,9,10,16]. Low temperature also affects hematological variables by increasing fibrinogen and VII clotting activity[7,30]. These effects could explain a large part of the increase in cardiovascular diseases in winter.

The consequence and mechanism of atmospheric pressure on AMI is unknown. One hospital-admission-based study in Athens failed to observe any effect of atmospheric pressure[18]. Whereas, two studies revealed that atmospheric pressure affects AMI independently[6,21]. Weinbacher et al[28] reported a weak negative correlation between systolic blood pressure and atmospheric pressure in hypertensive patients who did not respond to treatment. This association may offer a mechanism to explain the effect of atmospheric pressure on AMI. Furthermore, the deleterious effects of pressure higher than 1022 hPa on intracerebral hemorrhage reported by Chen et al[3] indicated that atmospheric pressure affects some cardiovascular and cerebrovascular diseases.

Although our study did not find any independent significant effect of atmospheric pressure on AMI, we observed an increasing linear relationship which was completely different from Danet's V-shaped relationship in France[6]. Climate is different between the two areas. Daily mean temperature in France was colder (ranged from –14.5 to 27.8°C; annual average daily mean temperature was 10.3°C). Daily atmospheric pressure was higher, and the range was wider (ranged from 964 to 1044 hPa; annual average daily mean pressure was 1017 hPa) compared to Hiroshima City. The discrepancy might be due to the fact that low pressure most likely happened on cold days in France, whereas in Hiroshima City, low pressure days were mostly accompanied by high temperatures. These controversial results indicated that complicated interactions of meteorological variables affect the results of studies performed in different geographical areas.

We actually found a strikingly significant interaction between atmospheric temperature and pressure. Daily events of AMI were highest on the days with low temperature, low pressure, together with high humidity, resulting in rain and/or snow in winter and early spring. This meteorological type is very impressive to clinicians in Hiroshima City who found that these days produced more AMI patients and hospital admissions. This finding is consistent with the former half of Danet's V-shaped relationship, which showed that daily incident event rates decrease up to 1016 hPa of atmospheric pressure[6]. Our result is also supported by Sarna et al[21] who declared that the highest risk of heart attack turned out to be relatively cold and moist weather, with low atmospheric pressure. Observed interactive effects can also be seen in the second worse meteorological type with low temperature, high pressure, and dry climate in winter, spring, and autumn. The third most dangerous meteorological type was associated with relatively high temperatures, high pressure, and dry climate in autumn and spring. It is comparatively safe on high temperature, low pressure, and low humidity days, which usually occur in summer, spring, and autumn.

The additional effect of atmospheric pressure is not uniform in all ranges of temperature; interaction between temperature and pressure is stronger on days of low/high temperature. For low pressure, the daily occurrence of AMI was highest in cold temperatures, but was lowest in warm temperatures. Limited by our present knowledge, we can not explain this phenomenon caused by the interaction of temperature and pressure. Further studies in places with similar climates to Hiroshima City are needed to verify our results.

We found dangerous meteorological types in Hiroshima City, concerning the interaction of atmospheric temperature and pressure. The results of this study also suggest that it might be possible to predict AMI events by knowledge of meteorological factors. Matsumura et al[15] have been trying to establish a prediction system of AMI based on meteorological factors, and have displayed their prediction results on The Hiroshima Prefecture Medical Association homepage every day since 2003. Prediction systems for AMI may have a practical public significance on primary and secondary prevention. It might also cause the public to pay more attention to, or to take preventive measures on high risk days. At the same time, local ambulance service centers and hospitals could prepare for rapid patient rescue.

Study limitations

The results of our analyses are limited to Hiroshima City. It is uncertain whether our results are valid to other geographical regions. Further studies based on data from different areas are required to establish a comprehensive relationship between meteorological variables and AMI.

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REFERENCES

1. **Argiles, A., Mourad, G. and Mion, C.** 1998. Seasonal changes in blood pressure in patients with end-stage rental disease trended with hemodialysis. N. Engl. J. Med. **339:** 1364–1370.
2. **Braga, A.L.F., Zanobetti, A. and Schwarts, J.** 2002. The effect of weather on respiratory and cardiovascular death in 12 US cities. Environ. Health Perspect **110:** 859–863.
3. **Chen, Z.Y., Chang, S.F. and Su, C.L.** 1995. Weather and stroke in a subtropical area: Ilan, Taiwan. Stroke **26:** 569–572.
4. **Collins, K.J., Easton, J.C., Belfield-smith, H., Exton-smith, A.N. and Pluck, R.A.** 1985. Effects of age on body temperature and blood pressure in cold environments. Clin. Sci. **69:** 465–470.
5. **Crawford, V.L.S., Mccann, M. and Stout, R.W.** 2003. Changes in seasonal death from myocardial infarction. Q. J. Med. **96:** 45–52.
6. **Danet, S., Richard, F., Montaye, M., Beauchant, S., Lemaire, B. and Graux, C.** 1999. Unhealthy effects of atmospheric temperature and pressure on the occurrence of myocardial infarction and coronary deaths. A 10-year survey: The Lille-World Health Organization MONICA Project. Circulation **100:** 1–7.
7. **Elwood, P.C., Beswick, A., O'Brein, J.R., Renaud, S., Fifield, R. and Limb, E.S.** 1993. Temperature and risk factors for ischemic heart disease in the Caerphilly prospective study. Br. Heart J. **70:** 520–523.
8. **Huynen, M.M.T.E., Martens, P., Schram, D., Weijenberg, M.P. and Kunst, A.E.** 2001. The impact of heat waves and cold spells on mortality rate in the Dutch population. Environ. Health Perspect **109:** 463–470.
9. **Imai, Y., Munakata, M., Tsuji, I., Ohkubo, T., Satoh, H. and Yoshino, H.** 1996. Seasonal variation in blood pressure in normotensive women studied by home measurements. Clin. Sci. **90:** 55–60.
10. **Jehn, M., Appel, L.J., Sacks, F.M. and Miller III, E.R.** 2002. The effect of ambient temperature and barometric pressure on ambulatory blood pressure variability. Am. J. Hypertens. **15:** 941–945.
11. **Kinjo, K., Kimura, Y., Shinzato, Y., Tomori, M., Komine, Y. and Kawazoe, N.** 1992. An epidemiological analysis of cardiovascular disease in Okinawa, Japan. Hypertens. Res. **15:** 111–119.
12. **Kloner, R.A., Poole, W.K. and Perritt, R.L.** 1999. When throughout the year is coronary death most likely to occur? A 12-year population based analysis of more than 220000 cases. Circulation **100:** 1630–1634.
13. **Kunes, J., Tremblay, J., Bellavance, F. and Hamet, P.** 1991. Influence of environmental temperature on the blood pressure of hypertensive patients in Montreal. Am. J. Hypertens. **4:** 422–426.
14. **MacMahon, S., Peto, R., Cutler, J., Collins, R., Sorlie, P. and Neaton, J.** 1990. Blood pressure, stroke, and coronary heart disease. Part 1, prolonged differences in blood pressure: prospective observational studies corrected for the regression dilution bias. Lancet **335:** 765–774.
15. **Matsumura, M., Usui, S., Shimazutsu, S., Takeuchi, S., Kagemoto, M. and Eboshida, A.** 2004. Predicting coronary heart disease. J. Hiroshima. Med. Ass. **57:** 469–475.
16. **Narang, R. and Wasir, H.S.** 1996. Seasonal variation in the incidence of hypertension and coronary artery disease. Int. J. Cardiol. **56:** 90–92.
17. **Pan, W.H., Li, L.A. and Tsai, M.J.** 1995. Temperature extremes and mortality from coronary heart disease and cerebral infarction in elderly Chinese. Lancet **345:** 353–355.
18. **Panagiotakos, D.B., Chrysohoou, C., Pitsavos, C., Nastos, P., Anadiotis, A. and Tentolouris, C.** 2004. Climatological variations in daily hospital admissions for acute syndromes. Int. J. Cardiol. **94:** 229–233.
19. **Pell, J.P. and Cobbe S.M.** 1999. Seasonal variations in coronary heart disease. Q.J. Med. **92:** 689–696.
20. **Pell, J.P., Sirel, J., Marsden, A.K. and Cobbe, S.M.** 1999. Seasonal variations in out of hospital cardiopulmonary arrest. Heart **82:** 680–683.
21. **Sarna, S., Romo, M. and Siltanen, P.** 1977. Myocardial infarction and weather. Ann. Clin. Res. **9:** 222–232.
22. **Seretakis, D., Lagiou, P., Lipworth, L., Signorello, L.B., Rothman, K.J. and Trichopoulos, D.** 1997. Changing seasonality of mortality from coronary heart disease. JAMA **278:** 1012–1014.
23. **Seto, T.B., Mittleman, M.A., Davis, R.B., Taira, D.A. and Kawachi, I.** 1998. Seasonal variation in coronary artery disease mortality in Hawaii: observation study. BMJ **316:** 1946–1947.
24. **Sheth, T., Nair, C., Muller, J., Yusuf, S. and Dphil, M.** 1999. Increased winter mortality from acute myocardial infarction and stroke: the effect of age. J. Am. Coll. Cardiol. **33:** 1916–1919.
25. **Spencer, F.A., Goldberg, R.J., Becker, R.C. and Gore, J.M.** 1998. Seasonal distribution of acute myocardial infarction in the second national registry of myocardial infarction. J. Am. Coll. Cardiol. **31:** 1226–1233.
26. **Wang, H., Matsumura, M., Kakehashi, M. and Eboshida, A.** 2005. Seasonal variations and the effect of atmospheric temperature on the incidence of coronary heart disease in Hiroshima, Japan. J. Health Sciences Hiroshima University **4:** 82–89.
27. **Weerasinghe, D.P., Macintyre, C.R. and Gubin, G.L.** 2002. Seasonality of coronary artery death in New South Wales, Australia. Heart **88:** 30–34.
28. **Weinbacher, M., Martina, B., Bart, T., Drewe, J., Gasser, P. and Gyr, K.** 1996. Blood pressure and atmospheric pressure. Ann. N.Y. Acad. Sci. **738:** 335–336.
29. **Wilmshurst, P.** 1994. Temperature and cardiovascular mortality. BMJ **309:** 1029–1030.
30. **Woodhouse, P.R., Khaw, K.T., Plummer, M., Foley, A. and Meade, T.W.** 1994. Seasonal variations of plasma fibrinogen and factor VII activity in the elderly: winter infections and death from cardiovascular disease. Lancet **343:** 435–439.
31. **Yoshida, M., Kita, Y., Nakamura, Y., Nozaki, A., Okayama, A. and Sugihara, H.** 2005. Incidence of acute myocardial infarction in Takashima, Shiga, Japan. Circ. J. **69:** 404–408.