

The Effect of Atmospheric Temperature and Pressure on the Occurrence of Acute Myocardial Infarction in Kaunas

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Key Words: acute myocardial infarction; atmospheric temperature; atmospheric pressure; meteorology.

Summary. *Objective.* The aim of the study was to evaluate the impact of meteorological variables (atmospheric temperature and pressure) on the daily occurrence of acute myocardial infarction (AMI).

Material and Methods. The study used the daily values of atmospheric temperature and pressure in 2000–2007. The meteorological data were obtained from the Lithuanian Hydrometeorological Service for Kaunas. The relative risks of event occurrence were computed for 5°C atmospheric temperature and for 10-hPa atmospheric pressure variations by means of the Poisson regression model.

Results. The occurrence of AMI and atmospheric temperature showed an inverse linear relationship, while the occurrence of AMI and atmospheric pressure, a positive linear relationship.

Among the youngest subjects (25–44 years old), no relationships were detected. Contrary, among the subjects aged 45–64 years and those aged 65 years and older, the occurrence of AMI significantly decreased with higher temperature ($P=0.001$ and $P=0.002$, respectively). A decrease in atmospheric temperature by 10°C reduced the risk of AMI by 8.7% in the age groups of 45–64 and 65 years and older and by 19% in the age group of 25 years and older. Among the first AMI cases, the risk increased by 7.5% in the age group of 45–64-year olds and by 6.4% in the age group of 25–64-year olds.

The relationship between atmospheric temperature and pressure, and AMI occurrence was found to be linear but inverse. An increase in atmospheric pressure by 10 hPa resulted in an increase in risk by 4% among the subjects aged 65 years and more and by 3% among the subjects aged 25 years and more.

Conclusions. Atmospheric temperature and pressure variations had the greatest effect on middle-aged and aging subjects (starting from 45 years). At younger age, the effect of such factors on the AMI risk was considerably lower.

Introduction

The effect of the weather and the climate on health and well-being has been known since the time of Hippocrates (1). Atmospheric pressure, temperature, and humidity are essential meteorological elements that influence not only physical but psychological well-being as well. There have been many studies conducted worldwide with the aim to establish the effects of atmosphere fronts, different types of the weather, and other geophysical factors on human health (1). Based on different studies, the weather interferes with well-being in at least two-thirds of the population (2–4). The weather has a greater impact on ill people. It has been demonstrated that weather changes lead to acute conditions and have effects on the course and

the outcomes of a disease. The more expressed the changes in meteorological and heliogeophysical factors and their combinations, the more observable the biological effects of the weather. It is estimated that patients with cardiovascular diseases (CVD) are highly meteosensitive subjects since up to 70% of their population report reactions to various meteorological changes. Meanwhile, healthy individuals almost do not react to meteorological changes (4). Studies have proven that the effects of meteorological factors on human health depend on age, gender, and general health status (5). Women are more sensitive to climate changes than men. During untoward climate events, patients with ischemic heart disease (IHD) suffer certain meteorotropic reactions (2, 3). Such patients are very sensitive to changes in atmospheric pressure and temperature. Similarly, a negative effect on the cardiovascular and respiratory systems is provoked by the fluctuation of heat waves (5–8). The rates of hos-

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pitalization and mortality from IHD increase with higher temperature. Various studies across the Nordic countries and Eastern Europe show a U-shaped relationship between mortality due to IHD and atmospheric temperature with the lowest mortality being at 15°C–20°C (9, 10). Meanwhile, in Spain and other countries in southern Europe, the optimal atmospheric temperature is 20°C–25°C (11, 12) and shows linear relationships. Regular weather changes are the main condition to establish the relationships with certain diseases. Cardiovascular and respiratory diseases mostly correlate with changes in atmospheric temperature (13, 14).

The aim of the present study was to investigate the association between meteorological variables (temperature and pressure) and acute myocardial infarction (AMI) morbidity in Kaunas (Lithuania).

Material and Methods

Kaunas-WHO Monica Registry. The IHD registry was launched in 1983 and includes Kaunas residents, i.e., subjects aged 25–64 years (verified data, including information on the recurrence of AMI) and subjects aged 65 years and older (nonverified data, no information on the recurrence of AMI). From 1983 to 2005, the IHD registry included about 220 000 subjects aged 25 to 64 years. The registry methodology is based on the recommendations of the World Health Organization (WHO) experts for the international program WHO MONICA (Multinational MONItoring of trends and determinants in CARDiovascular disease). AMI was defined using the WHO criteria. AMI or death due to the lesion of coronary vessels (epidemiological diagnosis category) was defined by following indicators: 1) course of the disease; 2) dynamic ECG changes specific to AMI; 3) changes in the activity of cardiospecific enzymes in blood serum; and 4) pathoanatomical investigation data.

Meteorological Data. The data about the meteorological indicators in Kaunas were obtained from the Lithuanian Hydrometeorological Service. The study included the mean atmospheric temperature (in centigrades) and pressure (in hectopascals) for every single day from 2000 to 2007.

Statistical Analysis. Statistical data analysis was conducted using the SPSS software for Windows, version 20.0. The indicators of AMI and meteorological variables were standardized per 100 000 population (Figs. 1 and 2). The effect of age was analyzed in 3 age groups (25–44 years, 45–64 years, and 65 years and older). For each age group, the mean daily morbidity rates were calculated for 1°C atmospheric temperature and 1-hPa atmospheric pressure according to the year of occurrence. The best fit was judged on the basis of the residual sum of squares and the value of the R^2 statistic. The

relative risk (RR) for AMI was calculated for every 5°C and 10°C of atmospheric temperature and for every 10 hPa of atmospheric pressure by using the Poisson regression model. The percentages of variation in the event rates according to meteorological variations were derived from the RR. For a given increase in a meteorological variable, the percentage of variation in the event rates was estimated by $100 \times (RR - 1)$. For a given decrease in a meteorological variable, the percentage of variation in the event rates was estimated by $100 \times (1 - RR) / RR$. The differences were considered as statistically significant at $P < 0.05$.

Results

The prevalence of AMI (first, recurrent, and total) as well as the average atmospheric pressure and temperature are presented by year in Table 1. Of the 8527 AMI cases during 8 years, 4998 (58.6%) occurred in men.

The occurrence of AMI and atmospheric temperature showed an inverse linear relationship (Fig. 1), while the occurrence of AMI and atmospheric pressure showed a positive association (Fig. 2).

Among the youngest subjects of the study (25–44 years old), no associations were found (Table 2). In contrast, among the people aged 45–64 years and 65 years and older, the occurrence of AMI significantly decreased with an increasing temperature ($P < 0.05$) (Table 2).

The highest effect of atmospheric temperature was observed for the first AMI among the subjects aged 45–64 years, and an increase of 5°C was associated with a 4% decrease in the AMI risk ($P < 0.05$) (Table 2).

Meanwhile, an increase by 10°C was associated with an 8.7% decrease in the total AMI risk (age groups of 45–64 and 65 years and older), and among the subjects aged 25 years and older, the risk decreased by 19% ($P < 0.05$). In case of the first AMI, the risk decrease was 7.5% for 45–64-year-old subjects and 6.4% for 25–64-year olds ($P < 0.05$) (data not shown).

Higher atmospheric pressure was significantly associated with a greater occurrence of AMI between 2 age groups (linear relationship) ($P < 0.05$): 65 years and more and 25 years and more. A significant increase in the number of cases of the first AMI was observed among the subjects aged 45–64 years (Table 2) ($P < 0.05$).

An increase in atmospheric pressure by 10 hPa was associated with a 4% increase in the risk of AMI among the subjects aged 65 years and more. Similarly, the risk was increased by 3% among the subjects aged 25 years and more.

The highest risk of the first AMI was observed among the subjects aged 45–64 years, i.e., a 4%

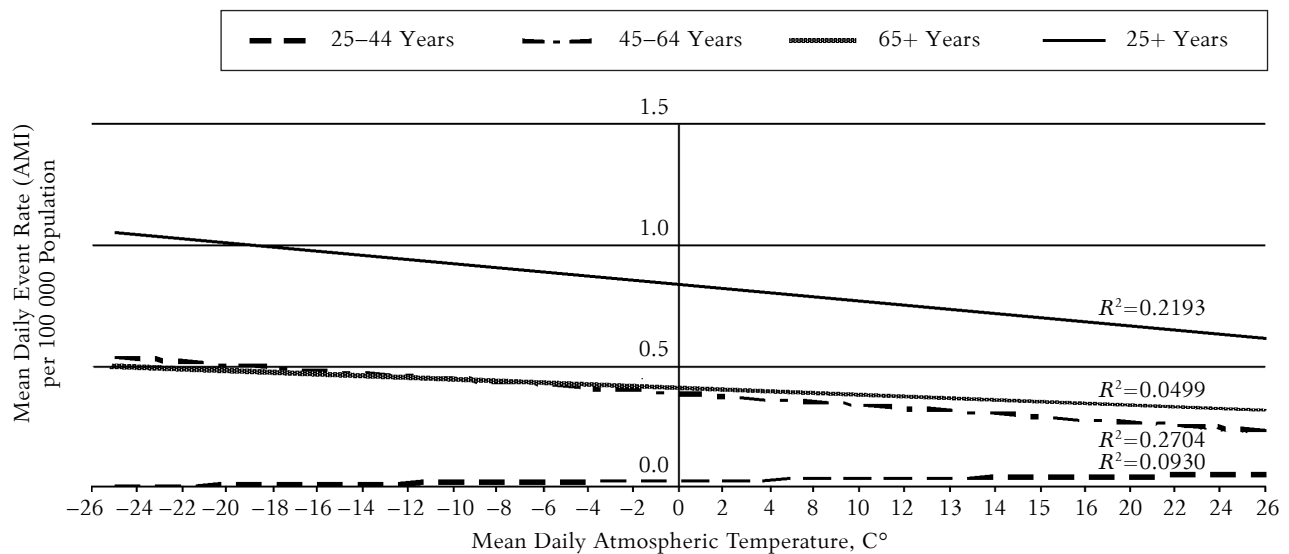


Fig. 1. Occurrence of AMI and atmospheric temperature: correlation by age groups

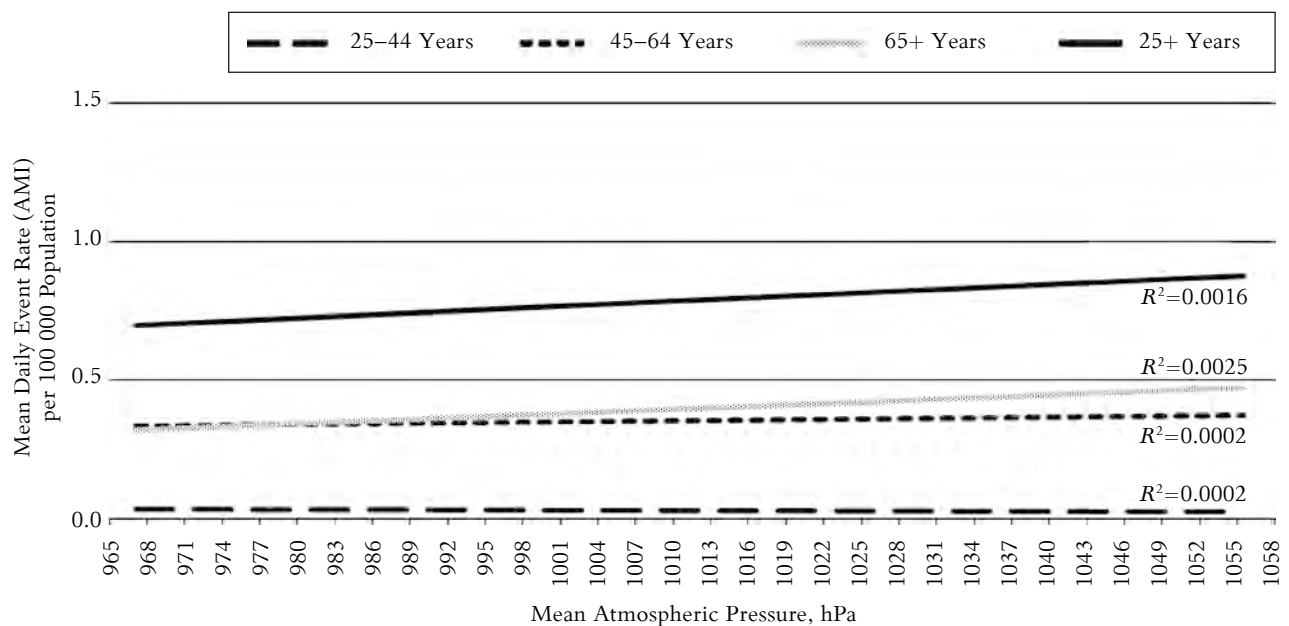


Fig. 2. Occurrence of AMI and atmospheric pressure: correlation by age groups

increase by every 10 hPa (Table 2). The risk of recurrent AMI was not significantly associated with meteorological factors studied in this study (possibly due to a small sample size).

Discussion

This is the first study in Kaunas that established the relationship between weather changes and CVD. Possible negative effects of atmospheric temperature and pressure on CVD morbidity have been proven in various countries worldwide, including Europe. Our study partly supports those findings but also shows some positive effects.

A study in France has reported that atmospheric temperature and the occurrence of AMI correlate in a linear manner, while atmospheric pressure and the occurrence of AMI show a V-shaped association. The lowest occurrence of AMI has been observed under atmospheric pressure of 1016 hPa (15). In France, like in our study, the lowest sensitivity to changes in atmospheric temperature was established among the subjects aged 44 years and less; there was no association between atmospheric temperature and AMI. On the other hand, in the age group of 45–54 years, an increase in temperature was significantly associated with a decreased risk of the AMI

Table 1. Occurrence of AMI and Meteorological Indicators in Kaunas, 2000–2007

Year	AMI Occurrence				Meteorological Indicators					
	First AMI	Recurrent AMI	Total AMI		Atmospheric Temperature, °C			Atmospheric Pressure, hPa		
	25–64 Years Old*	25–64 Years Old*	65+ Years Old†	All Age Groups	Mean	Min	Max	Mean	Min	Max
2000	353	186	482	1021	8.2	–15.3	22.1	1004.8	973.6	1055.5
2001	285	164	478	927	7.4	–15.7	26.2	1004.4	975.7	1034.4
2002	331	174	483	988	8.1	–19.9	26.3	1005.9	975.4	1035.1
2003	390	180	580	1150	7.0	–25.2	24.1	1007.0	973.3	1034.9
2004	380	153	559	1092	6.9	–16.7	22.0	1004.9	973.8	1028.7
2005	380	190	568	1138	7.1	–15.3	24.4	1006.6	968.7	1035.0
2006	393	171	547	1111	7.6	–23.7	26.0	1006.7	984.1	1038.6
2007	359	152	582	1093	8.1	–15.4	24.2	1004.5	967.1	1030.8
Total	2871	1370	4279	8520	7.6	–18.4	24.4	1005.6	974	1036.6

*First AMI (25–64 years old) + recurrent AMI (25–64 years old) = total AMI (25–64 years old).

†First and recurrent AMI are not specified.

Table 2. Relative Risk of AMI Occurrence in Relation to Changes in Atmospheric Temperature and Pressure

Age Group	N	Relative Risk (95% CI)	
		Atmospheric Temperature (Increase by 5°C)‡	Atmospheric Pressure (Increase by 10 hPa)**
Total AMI			
25–44 years	350	1.03 (0.97–1.10)	0.96 (0.86–1.06)
45–64 years	3891	0.97 (0.95–0.99)*	1.01 (0.98–1.05)
65+ years†	4279	0.97 (0.95–0.99)*	1.04 (1.01–1.07)*
Total (25+)	8520	0.97 (0.96–0.98)*	1.03 (1.01–1.05)*
First AMI			
25–44 years	284	1.02 (0.95–1.09)	0.96 (0.85–1.08)
45–64 years	2587	0.96 (0.94–0.98)*	1.04 (1.00–1.08)*
25–64 years	2871	0.97 (0.95–0.99)*	1.03 (0.99–1.07)
Recurrent AMI			
25–44 years	66	1.04 (0.93–1.16)	0.95 (0.79–1.16)
45–64 years	1304	0.98 (0.95–1.01)	0.99 (0.94–1.04)
25–64 years	1370	0.99 (0.96–1.01)	0.99 (0.94–1.04)

* $P < 0.05$. †First and recurrent AMI not specified. ‡Temperature interval from –26°C to 26°C.

**Pressure interval from 965 hPa to 1058 hPa.

occurrence. The most remarkable linear association was established in the age group of 55–64 years. In general, it can be concluded that for a decrease of 10°C in atmospheric temperature, there was an increase in the event rates by 13% in all the age groups, 11% in the age group of 45 to 54 years, and 18% in the age group of 55 to 64 years. The impact of atmospheric temperature was maximum for recurrent cases: a 10°C decrease in temperature was associated with a 26% increase in recurrent event rates (15).

The effect of changes in atmospheric pressure is more clearly observed among older people (aged 45–54 and 55–64 years). A change in pressure above or below the level of 1016 hPa is associated with an increased occurrence of AMI. A change in pressure by 10 hPa is associated with an increase in the occurrence of AMI by 11%–12% (15). As with temperature, the impact of atmospheric pressure was higher in recurrent events and older ages

(15). Some authors suggest that this effect can be mediated by increased blood pressure and viscosity as well as the lack of physical activity and nutrition factors (16, 17).

Pan et al. suggest that a lower capability of thermoregulation and sensitivity to atmospheric temperature among older subjects can result in a lower ability to retain the normal body temperature. Subsequently, the risk of hyperthermia and hypothermia increases, which in turn can lead to CVD (18).

Studies in the United Kingdom have demonstrated that IHD correlates with atmospheric temperature more than with a socioeconomic situation or a precipitation level. An analysis of the climate effect on arterial blood pressure has shown that both men and women are more sensitive in winter than summer (19).

Based on other studies, high temperature has a greater impact on cardiovascular diseases, which is in contrast to our findings. The highest mean daily

temperature in our study was 26.3°C; namely then, the occurrence of AMI was the lowest.

In Scotland, the majority of hospitalizations due to IHD among men aged less than 45 years were observed in spring and autumn. With older age, the number of hospitalizations in spring declined, while those in winter increased. Among women, the results were opposite, i.e., most hospitalizations were observed in winter and summer. The highest mortality due to IHD (both among men and women) was observed in winter and summer (20).

The issue of an association between atmospheric pressure and CVD has been less investigated. One of such studies has reported that a higher occurrence of AMI is related to atmospheric pressure below 1000 hPa (21). A somewhat different study on atmospheric pressure and CVD has been conducted in Vilnius (Lithuania) (22). The data have shown that irregular changes of atmospheric pressure have a great effect on well-being. The authors have found that during an increase in atmospheric pressure, maximum and minimum arterial blood pressure decreases, while the heart rate increases. In case of a decrease in atmospheric pressure, the opposite phenomena are observed. If atmospheric pressure demonstrates a significant decreasing manner throughout the day (10–27 hPa a day), the number of AMI cases increases by 31%. On the other hand, a decrease in atmospheric pressure by 0–5 hPa a day is associated with a lower CVD risk. In case of an increase in atmospheric pressure (by 10–36 hPa), primary arterial hypertension, hypertensive heart diseases, and paroxysmic tachycardia are more prevalent (22).

Researchers in Sweden analyzed the data of 300 000 subjects aged 25–64 years at Västerbotten and Norrbotten hospitals from 1985 to 1999. They reported that the changes in atmospheric temperature were not directly associated with AMI. The authors interpreted the changes in AMI according to atmospheric pressure fluctuations called Arctic oscillation (the latter has an effect on atmospheric temperature, humidity, and winds). The oscillation index ranges from –4 to 4 and reflects the extremes of high and low atmospheric pressure. Its change by 0.1 point is associated with an increase in AMI mortality by 8.3%. On the other hand, neither atmospheric temperature nor humidity nor pressure had remarkable effects on AMI. Only a large vari-

ation in atmospheric temperature was significantly associated with nonfatal AMI, i.e., an increase in atmospheric temperature by 1°C was related with a risk increase in nonfatal AMI by 1.5% (23). Many researchers suggest that the association between atmospheric temperature and the occurrence of AMI can be explained by disorders in body adaptation processes as well as increased sensitivity to atherosclerotic diseases (23). There can be such factors that lead to an increase in AMI risk under low atmospheric temperature like seasonal weight gain and lower physical activity in winter (23).

According to some studies, the dominant effect of meteorological factors in older age can be explained by genetic factors (24); meanwhile, Hata et al. have found that higher blood pressure in winter is determined by a higher activity of the sympathetic nervous system (19).

Preventive measures to suppress a negative effect of meteorological factors on the cardiovascular system can be person-oriented (proper clothing) or society-oriented (thermoisolation and conditioning systems indoors depending on temperature). Besides, higher mortality under decreasing temperature has been observed in warmer rather than colder regions of Europe. This can be due to insufficient personal and societal protection against coldness in countries with mild winters (25).

These and similar findings could be useful for healthcare and civil protection planning. However, based on similar designs, population studies in different countries or cities should be developed to further confirm and detail the influences of meteorological variables on AMI.

Conclusions

An increase in atmospheric pressure was found to be associated with a significant increase in the occurrence of acute myocardial infarction, meanwhile an increase in atmospheric temperature, with a significant decrease in the occurrence of acute myocardial infarction. Atmospheric temperature and pressure had the greatest effect on middle-aged and aging subjects (starting from 45 years old) in total and first AMI events.

Statement of Conflict of Interest

The authors state no conflict of interest.

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