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 (Monitoring Trends and Determinants in Cardiovascular Disease)

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Background—Associations between an increase in coronary heart disease occurrence and low atmospheric temperatures have been reported from mortality data and hospital admission registries. However, concomitant increases in noncardiovascular case fatality rates and selection bias of hospital cases may weaken this observation. In this study, we addressed the question of the relationships between fatal and nonfatal coronary diseases and meteorological variables in 10-year data (1985 to 1994) collected in a morbidity registry (Lille-WHO MONICA Project) monitoring 257 000 men from 25 to 64 years of age.

Methods and Results—The impacts of atmospheric temperature (in Celsius) and pressure (in millibars) on daily rates of myocardial infarction (MI) and coronary deaths were studied. Percentages of variation of event rates according to meteorological variations were derived from the relative risks estimated with a Poisson regression model. During the 10-year longitudinal survey, 3616 events occurred. Rates of events decreased linearly with increasing atmospheric temperature. For atmospheric pressure, we detected a V-shaped relationship, with a minimum of daily event rates at 1016 mbar. A 10°C decrease was associated with a 13% increase in event rates (P = 0.0001); a 10-mbar decrease <1016 mbar and a 10-mbar increase >1016 mbar were associated with a 12% increase (P = 0.0001) and an 11% increase (P = 0.01) in event rates, respectively. These effects were independent and influenced both coronary morbidity and mortality rates, with stronger effects in older age groups and for recurrent events.

Conclusions—This longitudinal study is the first to estimate the attributable effect of meteorological variables on MI morbidity in population and strongly argues for a systematic fight against cold in cardiovascular disease prevention, particularly in older ages and after a first MI. (Circulation. 1999;100:e1-e7.)

Key Words: registries • myocardial infarction • temperature, atmospheric • pressure, atmospheric • prevention

The winter peak of coronary death rates and the increase in hospital admission rates for myocardial infarction (MI) in winter have been related to the effect of low temperature.1–3 Kunst et al4 showed that the relationships between cold weather and coronary mortality were largely attributable to the direct effect of exposure to cold temperatures, taking into account the effects of influenza, air pollution, and season. However, the associations between coronary events and meteorological factors reported in mortality studies may be biased by the increase in case fatality rates observed in winter and with low temperatures that are related to noncardiovascular complications. Morbidity studies based on hospital admission data explored only selected events in patients who survived long enough to be admitted to hospitals. To the best of our knowledge, only 2 morbidity studies have been conducted in populations.5,6 These studies, based on 1- and 5-year data from morbidity registries, reported an excess of coronary deaths with low temperatures. A slight excess of definite MI rates for temperatures <0°C was detectable in Helsinki.5 Conversely, Enquêselassie et al6 in Australia failed to demonstrate any effect of temperature on nonfatal and incident cases of MI. Finally, meteorological factors other than atmospheric temperature were less frequently studied.

To clarify the possible associations between coronary artery diseases and meteorological variables, large population-based studies are needed, with exhaustive registration of morbidity and mortality events over long periods of time in geographical places where meteorological variables are homogeneous. We addressed the question of relationships between coronary event rates and meteorological variables in...
10-year data obtained from the Urban Community of Lille Ischemic Heart Disease Registry. This epidemiological program monitors coronary events in 522,000 men and women living in the north of France. This morbidity registry collaborates with the Multinational Monitoring of Trends and Determinants of Cardiovascular Disease (MONICA) project developed under the auspices of the World Health Organization (WHO). The impacts of meteorological variables on daily incident and recurrent rates of MI, fatal or nonfatal, occurring between 1985 and 1994 in men 25 to 64 years of age were explored.

### Methods

#### The Lille-WHO MONICA Registry

Details of the MONICA protocol have been published elsewhere. Briefly, the Lille MONICA collaborating center collects exhaustive standardized data on the incidence of acute MI in a geographically defined population. This population (257,000 men and 265,000 women, 1990 census) is located in the Nord district of France. Events occurring in patients 25 to 64 years of age are systematically recovered from private and public structures and from death certificates. All selected events are reviewed by a trained staff. Every coronary event must have its apparent onset within the study period between 1985 and 1994. For a given decrease in atmospheric pressure, the percentage of variation in event occurrence. Percentages of variation in event rates according to meteorological variables. Relations between mean daily event rates and atmospheric temperature or pressure were analyzed for the 3 age groups separately. Relative risks (RRs) of event occurrence, approximated by the OR, were computed for 5°C atmospheric temperature and for 10-mbar atmospheric pressure variations by use of a Poisson regression model. All RRs were adjusted for age group and year of occurrence. Percentages of variation in event rates according to meteorological variations were derived from RR. For a given increase in the meteorological variable, the percentage of variation in event rates was estimated by 100×(RR−1). For a given decrease in a meteorological variable, the percentage of variation in event rates was estimated by 100×(1−RR)/RR. This approach assumes that events are rare in the population (as observed for MI and coronary deaths) and that a log linear relation exists between event rates and meteorological variables.

### Results

The number of total, incident, recurrent, and fatal events per year and the annual means and ranges of daily atmospheric temperatures and pressures in the geographical area studied are shown in Table 1. Among the 3,314 events recorded during the 10 years of the survey for which the day of onset was available, 568 (17.1%) occurred in men 25 to 44 years of age, 949 (28.7%) in men 45 to 54 years of age, and 1,797 (54.2%) in men 55 to 64 years of age. Most of them (76.2%) were first events (incident cases), 21.1% were recurrent cases, and 38.3% were fatal events. Plots of the mean of daily event rates (per 100,000) according to the values of the meteorological variables. Relations between mean daily event rates and atmospheric temperature or pressure were analyzed for the 3 age groups separately. Relative risks (RRs) of event occurrence, approximated by the OR, were computed for 5°C atmospheric temperature and for 10-mbar atmospheric pressure variations by use of a Poisson regression model. All RRs were adjusted for age group and year of occurrence. Percentages of variation in event rates according to meteorological variations were derived from RR. For a given increase in the meteorological variable, the percentage of variation in event rates was estimated by 100×(RR−1). For a given decrease in a meteorological variable, the percentage of variation in event rates was estimated by 100×(1−RR)/RR. This approach assumes that events are rare in the population (as observed for MI and coronary deaths) and that a log linear relation exists between event rates and meteorological variables.

### Meteorological Data

Meteorological data of the area were obtained from Meteo-France, the French national meteorological institute. Daily mean atmospheric temperature (in Celsius) and daily mean atmospheric pressure (in millibars) were used.

### Statistical Analyses

Statistical analyses were performed with SAS software release 6.11 (SAS Institute Inc). For each age group, means of daily morbidity rates were calculated for 1°C atmospheric temperature and 1-mbar atmospheric pressure according to year of occurrence; the annual midyear population of each age group was used as a denominator. To determine the pattern of distributions, we plotted the mean of daily event rates (per 100,000) according to the values of the meteorological variables. Relations between mean daily event rates and atmospheric temperature or pressure were analyzed for the 3 age groups separately. Relative risks (RRs) of event occurrence, approximated by the OR, were computed for 5°C atmospheric temperature and for 10-mbar atmospheric pressure variations by use of a Poisson regression model. All RRs were adjusted for age group and year of occurrence. Percentages of variation in event rates according to meteorological variations were derived from RR. For a given increase in the meteorological variable, the percentage of variation in event rates was estimated by 100×(RR−1). For a given decrease in a meteorological variable, the percentage of variation in event rates was estimated by 100×(1−RR)/RR. This approach assumes that events are rare in the population (as observed for MI and coronary deaths) and that a log linear relation exists between event rates and meteorological variables.
(Figure 2). For atmospheric pressure, the lowest rate of events corresponded to 1016 mbar, and linear relationships were observed for increasing and decreasing pressures from 1016 mbar. In the model, therefore, we introduced atmospheric pressure as 2 mutually exclusive variables, 1 for atmospheric pressures \( \leq 1016 \) mbar and 1 for atmospheric pressures \( >1016 \) mbar. The relationships between mean of daily event rates per 100 000 men according to atmospheric temperature were plotted for the 3 age groups (Figure 1). In the youngest age group, no trend could be detected (RR, 0.97; 95% CI, 0.91 to 1.04) (Table 2). Conversely, a significant decrease in the mean of daily event rates with atmospheric temperature increase was observed in the 45-to-54-year group (RR, 0.95; 95% CI, 0.91 to 1.00); a much more pronounced effect was seen in the 55-to-64-year group (RR, 0.92; 95% CI, 0.89 to 0.96). For a 10°C decrease in atmospheric temperature, the increase in event rates was 13% for all age groups \((P<0.0001)\), 11% for the 45-to-54-year group \((P=0.05)\), and 18% for the 55-to-64-year group \((P<0.0001)\). Consistent results were obtained for the 3 types of events: fatal, incident, and recurrent events (Table 2). 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 \((P<0.0001)\) and an 11% increase in fatal and incident event rates \((P=0.05 \text{ and } P<0.001, \text{ respectively})\). A more pronounced effect was observed for older age groups for all 3 types of events.

The effect of atmospheric pressure on the occurrence of MI and coronary deaths was also more pronounced in the 45-to-54-year and 54-to-64-year groups. Increases and decreases in atmospheric pressure from 1016 mbar were both associated with increases in daily event rates. When atmospheric pressure was \(<1016 \) mbar, a 10-mbar decrease was associated with a 12% increase in event rates \((P<0.001)\). When atmospheric pressure was \(>1016 \) mbar, a 10-mbar increase was associated with an 11% increase in event rates \((P<0.01)\). Influences of atmospheric pressure on event rates were consistent for fatal, incident, and recurrent cases. As with temperature, the impact of atmospheric pressure was higher in recurrent events and for older ages (Table 2).

Because of the correlation between temperature and atmospheric pressure \((r=0.24 \text{ for low pressures and } r=-0.44 \text{ for high pressures})\), meteorological events were adjusted for each other. After this adjustment, the effects of both meteorological factors remained significant (Table 3). Thus, a 10°C decrease in atmospheric temperature was associated with an 11% increase in event rates for MI and coronary deaths \((P=0.001)\), whereas a 10-mbar decrease in atmospheric pressure \(<1016 \) mbar was associated with a 9% increase in event rates \((P<0.01)\), and a 10-mbar increase \(>1016 \) mbar was associated with a 5% increase \((P=\text{NS})\).

**Discussion**

This study is the first to estimate the impact of atmospheric variables on coronary heart disease morbidity in population over a long period of time compared with most previous studies that dealt with mortality rates from routine statistics or hospital admissions. The rigorous methodology and protocols...
developed in the frame of the WHO MONICA project allowed us to quantify over a 10-year period the relationships between atmospheric temperature and pressure and rates of coronary events. Atmospheric temperature and pressure independently influenced MI morbidity and mortality in the population. A 10°C decrease in atmospheric temperature was associated with a 13% increase in total coronary event rates, an 11% increase in incident and coronary death rates, and a 26% increase in recurrent event rates. Concerning atmospheric pressure, the relationship was V-shaped; the rates of MI and coronary deaths were minimum for 1016 mbar. A 10-mbar decrease in atmospheric pressure, <1016 mbar, was associated with a 12% increase in total coronary event rates, a 13% increase in coronary deaths, an 8% increase in incidence rates, and a 30% increase in recurrent event rates. For atmospheric pressure levels, >1016 mbar, a 10-mbar increase was associated with an 11% increase in total coronary event rates, an 18% increase in coronary deaths, a 7% increase in incidence rates, and a 30% increase in recurrent event rates.

The geographical area studied, located on the 50th parallel, enjoys an oceanic, temperate climate. In this flat region, the meteorological conditions are homogeneous throughout the area studied. Thus, daily climatic conditions are similar in all sites of the area, limiting the variability observed in larger geographical areas often considered in mortality studies. The MI and coronary death events were exhaustively collected and verified. Completeness of registration and standardization was ascertained according to the MONICA protocol. For 90 subjects (2.7% of the total population), history of MI was missing. For these patients, however, the monthly distribution of events according to their diagnostic category (MI or coronary death) was similar to that of the other patients, suggesting that these missing values did not affect results.

The potential deleterious effect of low temperatures on cardiovascular mortality and coronary deaths is supported by numerous studies in various countries. Our results are consistent with these observations. Conversely, the rare morbidity studies conducted in a population failed to demonstrate any consistent association between the occurrence of incident and nonfatal MI and low temperatures. The statistical power of our study allowed us to detect an effect of low temperatures on incident, recurrent, and fatal coronary event rates. Moreover, convincing arguments about the increase in cardiovascular risks with cold exist. Increases in blood pressure and viscosity may underlie the effect of cold on coronary event occurrence. Seasonal and temperature variations of blood pressure, serum lipid, and fibrinogen levels have been also described. Reduced physical activity and diet modifications in winter may also be involved in these relationships.

Other reports suggested an increase in cardiovascular mortality associated with heat. Kunst et al. in the Netherlands found that 26% of heat-related mortality was due to cardiovascular disease, and Pan et al. in Taiwan described higher coronary death rates for cold and heat with a minimum death rate occurring at 26°C. In our study, although the highest temperature was 28°C, mean daily atmospheric temperatures of >25°C were unusual (<10 days in 10 years of survey) and
did not allow us to confirm this observation on morbidity rates.

The consequences of atmospheric pressure on cardiovascular diseases have been studied less frequently, probably because most studies analyzed only monthly or seasonal variations of event rates. Indeed, variability of monthly atmospheric pressure is weaker than daily variations, often leading to inconclusive results. One study reported higher daily rates of MI cases with atmospheric pressures \(1000\) mbar. \(5\) Chen and colleagues \(13\) found an association between intracerebral hemorrhage and atmospheric pressures \(1022\) mbar, whereas Lejeune et al \(14\) found that atmospheric pressure was lower the day before the occurrence of subarachnoid hemorrhages. Finally, one hospital-based study showed that atmospheric pressure might be a discriminant factor between MI, more often associated with low pressures, and intracerebral hemorrhage, more often associated with high pressures. \(15\) The V-like relationship observed in the present study needs to be confirmed. However, the consistency of our results regardless of category, the detection of the lowest rate of events at the point that commonly defined low and high atmospheric pressures, and the persistence of the effects after adjustment of atmospheric temperature strongly argued for a specific and independent effect of atmospheric pressure on MI mortality and morbidity. A weak negative effect of atmospheric pressure (range, 720 to 750 mbar) on blood pressure levels has been reported in hypertensive patients who did not respond to treatments \(16\); this association between atmospheric pressure and a common risk factor of coronary artery disease may offer a clue in our exploration of a biological mechanism underlying the effect of atmospheric pressure on coronary heart disease.

We reported stronger effects of meteorological variables on recurrent case rates. This group of cases is composed of patients who resisted a first MI. In this subgroup, the control of classic risk factors of MI with secondary prevention, even limited, \(17\) and development of a chronic cardiac disease afterward may explain their increased vulnerability to other less common noncontrolled risk factors such as meteorological variables. The increasing influence of atmospheric temperature and atmospheric pressure as age increased in all subgroups has previously been described for temperature. \(1\) The predominance of the effects of the meteorological factors after 55 years of age could be explained both by the impact of strong genetic determinants of MI before 55 years of age \(18\) and by body temperature control mechanisms becoming less efficient with age. \(19\)

Finally, our results indicating a relationship between meteorological variables and coronary event rates, particularly for recurrent event rates, strongly suggest that fighting against

<table>
<thead>
<tr>
<th>Age, y</th>
<th>n</th>
<th>RR (95% CI)</th>
<th>Atmospheric Temperature (5^\circ)C</th>
<th>Low Atmospheric Pressure (-10) mbar</th>
<th>High Atmospheric Pressure (10) mbar</th>
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</thead>
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<tr>
<td>MI and coronary deaths</td>
<td></td>
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<tr>
<td>25–44</td>
<td>568</td>
<td>0.97 (0.91–1.04)</td>
<td>0.92 (0.78–1.09)</td>
<td>0.95 (0.81–1.13)</td>
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<td>45–54</td>
<td>949</td>
<td>0.95 (0.91–1.00)</td>
<td>1.12 (1.00–1.25)</td>
<td>1.10 (0.97–1.25)</td>
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<tr>
<td>55–64</td>
<td>1797</td>
<td>0.92 (0.89–0.96)</td>
<td>1.18 (1.09–1.28)</td>
<td>1.16 (1.06–1.27)</td>
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<tr>
<td>25–64</td>
<td>3314</td>
<td>0.94 (0.91–0.96)</td>
<td>1.12 (1.05–1.19)</td>
<td>1.11 (1.04–1.18)</td>
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<td>25–44</td>
<td>160</td>
<td>1.03 (0.91–1.17)</td>
<td>0.99 (0.73–1.33)</td>
<td>1.01 (0.74–1.38)</td>
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<td>45–54</td>
<td>302</td>
<td>1.00 (0.92–1.10)</td>
<td>0.99 (0.89–1.34)</td>
<td>1.13 (0.91–1.40)</td>
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<td>819</td>
<td>0.92 (0.87–0.97)</td>
<td>1.17 (1.04–1.32)</td>
<td>1.23 (1.09–1.40)</td>
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<td>25–64</td>
<td>1281</td>
<td>0.95 (0.91–0.99)</td>
<td>1.13 (1.02–1.24)</td>
<td>1.18 (1.06–1.31)</td>
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<tr>
<td>Incident cases</td>
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<td>491</td>
<td>0.95 (0.89–1.02)</td>
<td>0.92 (0.77–1.10)</td>
<td>1.02 (0.85–1.21)</td>
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<td>750</td>
<td>0.96 (0.90–1.01)</td>
<td>1.06 (0.93–1.21)</td>
<td>1.06 (0.92–1.22)</td>
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<td>1283</td>
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<td>1.16 (1.05–1.27)</td>
<td>1.10 (0.99–1.23)</td>
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<td>2524</td>
<td>0.95 (0.92–0.98)</td>
<td>1.08 (1.01–1.16)</td>
<td>1.07 (1.00–1.16)</td>
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<td>Recurrent cases</td>
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<td>65</td>
<td>1.07 (0.88–1.30)</td>
<td>1.00 (0.65–1.53)</td>
<td>0.54 (0.29–1.00)</td>
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<tr>
<td>45–54</td>
<td>178</td>
<td>0.93 (0.83–1.04)</td>
<td>1.37 (1.09–1.73)</td>
<td>1.29 (0.98–1.70)</td>
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<tr>
<td>55–64</td>
<td>457</td>
<td>0.85 (0.79–0.91)</td>
<td>1.31 (1.12–1.53)</td>
<td>1.43 (1.21–1.69)</td>
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<tr>
<td>25–64</td>
<td>700</td>
<td>0.89 (0.84–0.94)</td>
<td>1.30 (1.15–1.47)</td>
<td>1.30 (1.13–1.49)</td>
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</table>

RR was adjusted for year of occurrence.

\*P<0.05; †P<0.01; ‡P<10^{-4}; §P<10^{-6}.

Low atmospheric pressure indicates lower than 1016 mbar; high atmospheric pressure, higher than 1016 mbar.

¶Adjusted for year of occurrence and age group.
cold is important in cardiovascular prevention. Individual prevention with clothes suited to cold weather in winter and collective prevention with the improvement of heat insulation of living quarters may be implemented. This advice is supported by the results of 2 recent studies. The Eurowinter group observed that increases in mortality rates with decreases in temperatures were higher in warmer regions of Europe than in colder. This may be due to inadequate individual and collective protection against cold in those countries with mild winters.20 Moreover, Seretakis et al 21 showed that changes in seasonal patterns in coronary mortality in the United States were compatible with gradual expansion of adequate heating and use of air conditioning. Other population studies in different countries based on similar designs should be developed to further confirm and detail the influences of meteorological variables on coronary heart disease occurrence. These reports should emphasize the importance of adequate temperature conditions as prevention.

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References

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