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# Effects of ambient temperature, humidity, and other meteorological variables on hospital admissions for angina pectoris

Maurizio G Abrignani<sup>1</sup>, Salvatore Corrao<sup>2</sup>, Giovan B Biondo<sup>1</sup>, Renzo M Lombardo<sup>1</sup>, Paola Di Girolamo<sup>3</sup>, Annabella Braschi<sup>4</sup>, Alberto Di Girolamo<sup>1</sup> and Salvatore Novo<sup>3</sup>

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## Abstract

**Background:** Seasonal peaks in cardiovascular disease incidence have been widely reported, suggesting weather has a role.

**Design:** The aim of our study was to determine the influence of climatic variables on angina pectoris hospital admissions.

**Methods:** We correlated the daily number of angina cases admitted to a western Sicilian hospital over a period of 12 years and local weather conditions (temperature, humidity, wind force and direction, precipitation, sunny hours and atmospheric pressure) on a day-to-day basis. A total of 2459 consecutive patients were admitted over the period 1987–1998 (1562 men, 867 women; M/F = 1:8).

**Results:** A seasonal variation was found with a noticeable winter peak. The results of Multivariate Poisson analysis showed a significant association between the daily number of angina hospital admission, temperature, and humidity. Significant incidence relative ratios (95% confidence intervals/measure unit) were, in males, 0.988 (0.980–0.996) ( $p = 0.004$ ) for minimal temperature, 0.990 (0.984–0.996) ( $p = 0.001$ ) for maximal humidity, and 1.002 (1.000–1.004) ( $p = 0.045$ ) for minimal humidity. The corresponding values in females were 0.973 (0.951–0.995) ( $p < 0.017$ ) for maximal temperature and 1.024 (1.001–1.048) ( $p = 0.037$ ) for minimal temperature.

**Conclusions:** Environmental temperature and humidity may play an important role in the pathogenesis of angina, although it seems different according to the gender. These data may help to understand the mechanisms that trigger ischemic events and to better organize hospital assistance throughout the year.

## Keywords

Angina pectoris, hospital admission, weather, meteorology

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## Introduction

Various epidemiological studies have reported greater coronary heart disease (CHD) and acute myocardial infarction (AMI) incidence and mortality both in winter<sup>1–7</sup> and in extremely hot summers.<sup>8–10</sup> Many authors have postulated that weather-related variables may explain these seasonal trends. We<sup>11</sup> have previously shown an association between minimal temperature, maximal humidity and AMI hospital admissions in Sicily.

Very few studies have investigated variations in hospitalizations due to angina pectoris in relation to

climatic variables.<sup>6</sup> A better understanding of these seasonal patterns may provide novel avenues in cardiovascular prevention.

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The aim of this study was to explore the short-term association between some meteorological variables and angina hospital admissions.

## Methods

We retrospectively analyzed the number of daily hospital admissions due to angina pectoris in a single center with an intensive Coronary Care Unit (CCU) during a 12-year period. Trapani, located on the 37th parallel, in the Mediterranean island of Sicily, has a mild climate. The hospital and its CCU serve an area of about 1,50,000 inhabitants and no other emergency facilities are available in the territory. Since measuring the daily exposure to meteorological agents of a population is impractical and expensive, epidemiologists agree to use ambient meteorological data measured at weather stations.<sup>12</sup> This ecologic approach assumes that in a specified geographic area all persons experience the same exposure. Data were obtained from the meteorological station at the local Birgi air force base. The environmental and admission data therefore covered the same geographical area. Measurements every 3 h from the weather center provided mean daily values of each parameter: minimal and maximal temperature (degrees Celsius), minimal and maximal atmospheric pressure (millibars), minimal and maximal relative humidity (percent), daily bright sunshine (hours), daily rain (yes/no), wind direction (degrees) and daily mean wind speed (knots).

Daily admissions and patients' data were obtained by the hospital registry database. The study population included all consecutive patients with angina admitted from 1 January 1987 to 31 December 1998. The diagnosis of angina pectoris was primarily a clinical one, based on typical cardiac chest pain lasting less than 30 min and typical electrocardiographic changes either at rest or during provocative tests.

### Statistical analysis

Number of patients and millimeters (mm) of rain are expressed as monthly sums while all the other variables as monthly means. Continuous variables are shown as median (interquartile range). Absolute frequencies,

both per years and months, were computed for angina events. Multivariable fractional polynomial models analysis was performed to select the model that best predicted the outcome variable. A *p* value of 0.1 was used as cut-off for inclusion into the model. The final model of Poisson regression analysis was built with a backward selection of variables. In order to assess its adequacy, we looked at the basic descriptive statistics for the event count data. The count mean and variance were not very different, so our model was not over-dispersed and the linearity of climatic variables was confirmed. We used a scale parameter as a measure of over-dispersion as well; this is equal to the Pearson chi-square statistic divided by the number of observations minus the number of parameters (covariates and intercept). In the final model we have also included days of the week and public holidays, without observing any effect of these variables. If Pearson goodness-of-fit statistic gave a significant result, negative binomial regression was performed instead of the Poisson regression computation. We used a bootstrap procedure (100 replications per time) to validate the regression model and compute standard errors and 95% confidence intervals. STATA/SE, version 9.2 for Windows (StataCorp, College Station, Texas), was used in data analysis.

## Results

A total of 2459 consecutive patients was discharged with a diagnosis of angina over the studied period (1562 men, 867 women; M/F = 1:8, mean age  $66.9 \pm 9.1$ ; mean age in males  $65.6 \pm 8.1$ , mean age in females  $69.3 \pm 7.9$ ).

Table 1 shows seasonal admissions for angina pectoris. Fewer admissions occur during the summer, whereas the greatest number occurs during the spring in total population and in males, and during the fall in females. Seasonal distribution of angina admissions according to age is shown in Figure 1. The greatest number of admissions occurred in winter only in middle-aged men, whereas middle-aged-elderly women showed a noticeable variability between summer and other seasons.

**Table 1.** Seasonal absolute number of hospital admissions for angina pectoris

	Total population	Males	Females
Winter	629	426	203
Spring	668	436	232
Summer	543	367	176
Fall	642	384	258

Figure 2 shows the monthly total and single gender distributions of hospital angina admissions; there was a trend toward more admissions in January and July in males and in October in females. However, median variability (adjusted for ties) among the monthly means was not significant at the post hoc inter-month pairwise comparisons.

The median values and interquartile ranges of the monthly means of the meteorological variables in the

considered period (4383 days) are the following: wind direction 238.20° (207.90–255.58); wind force 20.76 knots (18.48–23.19); maximal temperature 20.88°C (16.78–27.34); minimal temperature 12.76 (8.74–18.17); maximal humidity 95.03% (92.67–96.26); minimal humidity 60.35% (55.13–65.24); maximal pressure 1016.38 mbars (1014.59–1018.74); minimal pressure 1013.47 mbars (1011.77–1015.723); sunny hours 7.08 h (5.23–9.29).

The results of multivariate regression analyses are shown in Table 2. Overall, a negative significant association was observed in the incidence relative ratio (IRR) (95% confidence intervals/measure unit) between the daily number of angina admission and maximal temperature and maximal humidity, while the association was positive for minimal humidity. In males, data on humidity were confirmed but a negative association was observed with minimal temperature. In females, in contrast, daily mean numbers of angina admissions showed a positive association with minimal temperature, and a negative one with maximal temperature, with no significant changes for humidity.

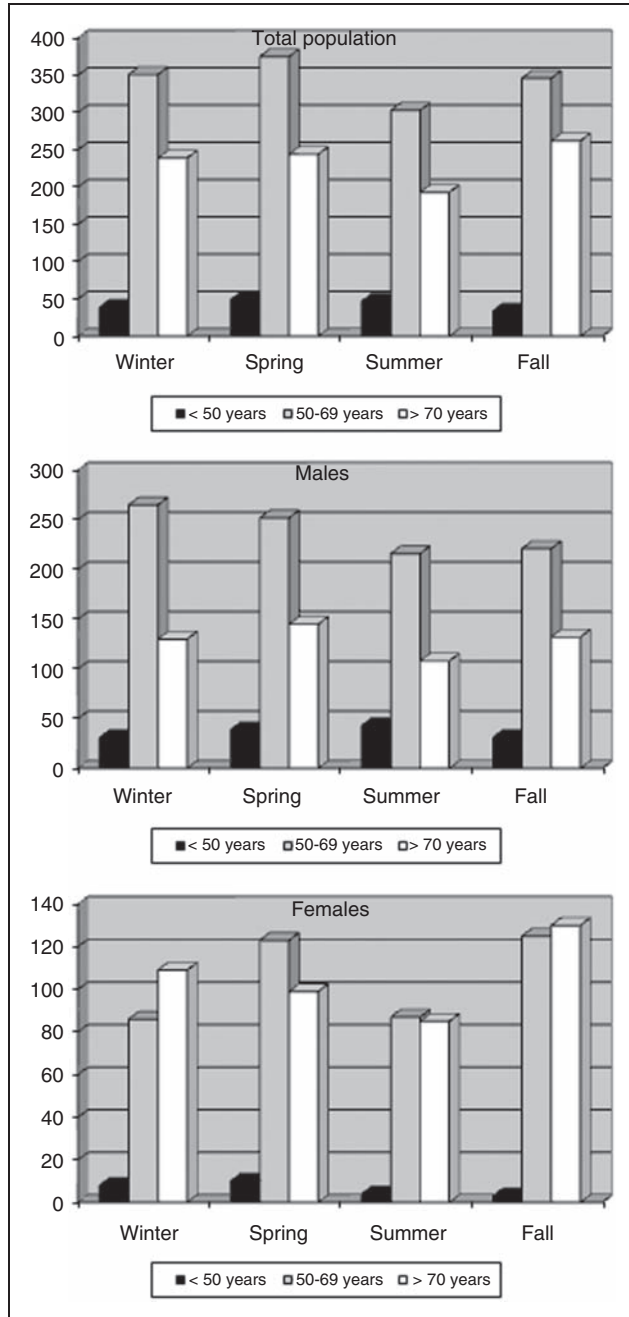
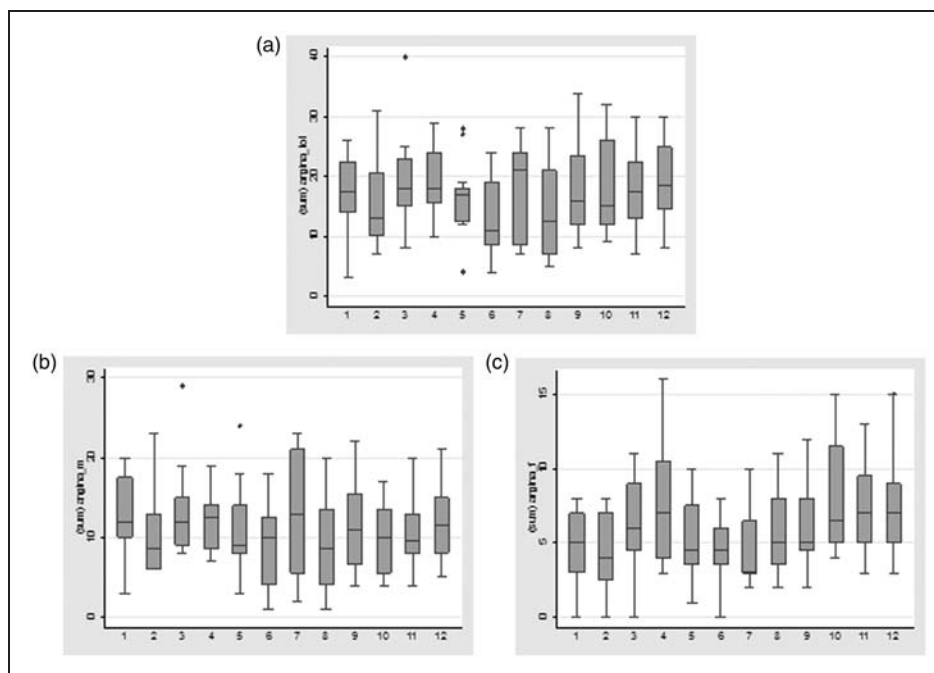


Figure 1. Seasonal distribution, in absolute numbers, of angina admissions in different age groups.

### Discussion

Considerable advances have been made in identifying the conditions predisposing to atherosclerosis,<sup>13</sup> but little is known about the contributory factors leading to angina. The greater incidence of cardiovascular mortality and non-fatal AMI during the winter is well known.<sup>1,3-5,11,14-32</sup> Possible mechanisms involve the complex relations between seasons and pathophysiological exogenous and endogenous individual factors. Conventional risk factors, such as blood pressure, lipids, coagulation factors, and glucose tolerance, as well as a number of hormones and environmental factors (such as air pollution and acute infections), show marked seasonal variations with a winter clustering.<sup>15-18</sup> In addition, humans display different seasonal behavior in diet, activity, mood disorders,<sup>18</sup> housing, and smoking habits.<sup>19</sup> Our data, in contrast, do not show a greater angina incidence in winter; in particular, no significant changes have been observed among monthly means admissions. Very few studies, indeed, have investigated this phenomenon, besides cumulating angina and AMI admissions.<sup>6,20,21</sup> Female hospital admissions exhibit a more marked seasonal variation, as women tend to present angina at a later age and the association between seasons and hospitalizations tends to be stronger in the elderly.<sup>20-22</sup> However, also in elderly women the greatest number of admissions for angina occurred in the fall and not in winter. Thus, in conclusion, it could be argued that seasonal influences, globally, differ between angina pectoris and AMI.



**Figure 2.** Box-whisker plots showing the average daily number of hospital admissions for angina in every month of the studied period. (a) total population; (b) males; (c) females.

**Table 2.** Multivariate regression analysis: results by gender

Variables	IRR (95% CI)	<i>p</i>
Total <sup>a</sup>		
Maximal temperature (°C)	0.992 (0.986–0.998)	0.013
Maximal humidity (%)	0.991 (0.985–0.996)	0.002
Minimal humidity (%)	1.002 (1.001–1.004)	0.004
Men <sup>b</sup>		
Minimal temperature (°C)	0.988 (0.980–0.996)	0.004
Maximal humidity (%)	0.990 (0.984–0.996)	0.001
Minimal humidity (%)	1.002 (1.000–1.004)	0.045
Women <sup>b</sup>		
Maximal temperature (°C)	0.973 (0.951–0.995)	0.017
Minimal temperature (°C)	1.024 (1.001–1.048)	0.037
Maximal humidity (%)	0.994 (0.985–1.003)	0.164 NS

IRR, incidence relative ratio (for single measure unit); CI, confidence interval. <sup>a</sup>Negative binomial regression; <sup>b</sup>Poisson analysis.

Our results also displayed a trend toward more admissions in January and July in males and October in females. Although this is a descriptive data, not related to the major aim of the study, it is possible to speculate that in females, in whom microvascular angina is more common,<sup>32</sup> the beginning of the cold season could exacerbate the appearance of angina. In contrast, in males, the extremely cold temperature in

January may have a role in relation to major epicardial vessel constriction. It is also possible that in July, anginal episodes may follow greater open air activity in men.

As regards weather parameters, the peculiar homogeneous meteorological conditions of our flat geographical area, enjoying a Mediterranean, temperate climate, limit the variability observed in larger locations.

Our time-series analyses revealed a significant association between ambient temperature, relative humidity, and angina hospital admissions. The inverse relationship between temperature and myocardial infarction is well known;<sup>1,7,11,20–26</sup> conversely, it has been hypothesized that a worsening of angina occurs in cold weather.<sup>4,20–21,23–25</sup> Our study confirms that a reduction in maximal temperature is associated with more hospital angina admissions in total population and in females, but not in men, in whom the phenomenon is significant as regards a decrease in minimal temperature. Mechanisms leading to the possible influence of cold on angina are most likely multifactorial. Different heart and circulation adjustments occur when humans are acutely exposed to low temperatures. The increase in the circulating levels of catecholamines, secondary to thermoreceptor activation,<sup>27</sup> leads to an increase in blood pressure, heart rate, and left ventricular end-diastolic pressure and volume.<sup>27–30</sup> The increased cardiac work and peripheral resistance contributes to greater heart oxygen consumption and hence a reduction of ischemic threshold, clinically relevant when the coronary circulation is already compromised.<sup>28</sup> Finally, cold exerts other biological negative effects on hemostasis, rheological factors, lipids (probably related to hemoconcentration), salt intake, alcohol consumption, and body weight gain.<sup>14,29–31</sup> Surprisingly, in females the number of angina admissions is, in contrast, positively correlated with an increase in minimal temperature. It is not clear whether this phenomenon, observed also by Ebi,<sup>21</sup> may be related to the different coronary anatomy in women: they have less extensive coronary atherosclerosis, lower coronary size, and lower collateral circulation than males.<sup>32</sup>

We observed lower angina daily rates during the summer in the whole population, even if in males there was a relatively higher number of admissions in July. Notwithstanding the observed association between high temperatures and AMI,<sup>8–10</sup> the statistical power of our multivariate analyses does not confirm an association between increases in maximal temperature and incidence of angina.

A negative significant relation between angina admissions and maximal ambient humidity was also observed. In contrast, an increase in minimal humidity is associated with more angina admissions in males and in the total population. Very few data are available relating to this argument. Panagiotakos<sup>20</sup> found a positive association between relative humidity and hospital admissions for acute coronary syndromes, including angina. One could hypothesize that when air has a high percentage of humidity, the perspiration and the processes of temperature homeostasis might be hindered, thus increasing respiratory fatigue and heart

rate. However, this mechanism may be important only in more severe ischemic forms.

The consequences of atmospheric pressure on cardiovascular diseases have been less studied. Although ambient pressure had a statistical impact on the incidence of angina in Turkey and Switzerland,<sup>25,33</sup> we did not observe any significant relation between atmospheric pressure and angina incidence. Furthermore, our study did not show any significant relationship between sunlight hours, wind force and direction, rain, and angina admissions, suggesting these variables as weak ischemic triggers.<sup>11,34</sup>

There are some potential limitations to our study. First, it was a single-center-based retrospective analysis. Second, morbidity studies based on hospital admissions explore only events in selected patients. Therefore, studies on CHD based on secondary care data may not accurately reflect the disease in the general population. However, in the Morbidity information QUery and report SynTax (Myquest),<sup>6</sup> a software collecting data from general practitioner, there was also a seasonal variation in angina diagnosis. However, in studies in which computer databases are the only sources, completeness and accuracy of the data can limit the conclusions. Besides, the temperature of a specified geographic area may not accurately represent the actual individual temperature exposure, which is influenced by personal behaviors. Furthermore, data on concomitant air pollution, known to have negative effects on various cardiopulmonary parameters<sup>12,35</sup> were not available. However, the studied zone is free from heavy industries, and the major air pollutant is car traffic, thus minimizing the effect of this parameter.

The weather-related events on ischemic syndromes have several potential implications. Public health actions have been proposed to reduce the population vulnerability to the adverse consequences of climate variability, such as educational behavioral and social measures.<sup>34</sup> The medical system should take into consideration seasonal variations in emergencies<sup>36</sup> to avoid potential mismatch between the occurrence of acute cardiovascular events and medical service capacities. Other large, exhaustive, population-based cohort studies over long periods in geographical areas with homogeneous meteorological variables should be carried out to further detail climatic influences on CHD occurrence. The relevance of these studies is growing sharply in relation to the recent climatic changes, as thermal stress is likely to become more common as the earth warms and the climate becomes more variable.<sup>37</sup>

In conclusion, according to our data environmental temperature and humidity may play an important role in the pathogenesis of angina, although their role seems different according to gender.

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## Conflicts of interest

None declared.

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