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WINTER CLASSIFICATION OF AIR MASSES AND WEATHER TYPES FOR THE FORECASTING OF HOSPITAL ADMISSIONS FOR MYOCARDIAL INFARCTION IN FLORENCE, ITALY

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1. ABSTRACT

Recently, interest in the impact of the weather and climate on human health has become an issue of much greater significance. The aim of this study was to evaluate the relationship between the risk of hospital admission for myocardial infarction and daily weather conditions, according to a synoptic climatological approach. Data for daily admissions for myocardial infarction were provided by the Administration of Careggi Hospital in Florence for the period 1998-2003. Hourly meteorological data was obtained from a weather station located in the main urban park of Florence and managed by the Institute of Biometeorology of the National Research Council. The analyses were concentrated on winter season, when the maximum peak of hospitalization for myocardial infarction occurred. A principal component analysis and a successive clustering technique was applied to identify typical air masses characteristics of the Florentine area. A multiyear comparison of MI admissions between air mass types was made by the calculation of a myocardial infarction admission index. Sequences of air mass types and their impact on hospitalizations were also investigated. Two antyciclonic air mass types (the continental anticyclonic and the anticyclonic mixed tropical maritime and continental) and the cyclonic one, were often associated with high mean daily admissions for myocardial infarction, especially when consecutive days with these air mass types occurred.

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2. INTRODUCTION

There are many epidemiological evidences that cold weather conditions could represent aggravating circumstances or trigger off factors for cardiovascular diseases (CVD), in particular for myocardial infarction (MI).

Relationships between weather conditions and hospital admissions for CVD have been so far investigated through different approaches: a) by using a single meteorological variable; b) by considering the combined effects of several meteorological parameters; c) by a synoptic climatological approach. In the first case, weather is treated as univariate and the air temperature represents the variable more often correlated with the hospitalizations for CVD (Marchant et al., 1993; Danet et al., 1999). On the other hand, a small number of studies surveyed these relationships by using biometeorological indices based on simple empirical formulas, often considering the weather as bivariate, generally air temperature and relative humidity or wind velocity (Morabito et al., 2002; Rusticucci et al., 2002; Panagiotakos et al., 2004). All these approaches have the limit to consider only several meteorological parameters and can not describe the simultaneous action of the weather complex. On the other hand, the use of synoptic climatological classifications can be of considerable utility to the applied research as it produces meteorologically homogeneous groups of meteorological events, that are expression of local climatic conditions, which can be used to evaluate the potential synergistic impacts of an entire suite of weather elements on an environmental or biological parameter sensitive to weather (Barry and Perry, 1973).

The aim of this study was to evaluate, for the winter period, the relationship between the risk of hospital admission for myocardial infarction and daily weather conditions according to a synoptic climatological approach for the area of Florence, central Italy. In this study the methodology adopted follows that which was applied by McGregor in a study conducted in a city of North Europe, Birmingham, UK (McGregor et al., 1999).

3. MATERIALS

Meteorological data

Hourly meteorological data were provided for the winters (December – February) from 1998-1999 to 2002-2003 by the weather station of Cascine (λ = 11°11' E; Φ = 43°47' N), located in the main urban park of Florence and managed by the Institute of Biometeorology of the National Research Council. Seven meteorological variables were considered: 1) dry bulb temperature; 2) cloud cover; 3) saturation pressure deficit; 4) sea level atmospheric pressure; 5) wind speed; 6) *u* (East–West) component of the wind; 7) *v* (North–South) component of the wind. These variables are considered to be good indicators of air mass characteristics (McGregor et al., 1999).

Hospital discharge data

Computerized inpatient hospital discharge data for myocardial infarction (MI), over the 5 winters survey, were provided by the Administration of Careggi Hospital (source Azienda Ospedaliera di Careggi), the biggest and the main Regional hospital in Tuscany. Only data of people resident in the Florentine area were considered. Discharge diagnoses were coded by professional nosologists according to International Classification of Diseases, Ninth Revision Clinical Modification (ICD-9-CM: 410 - 410.92).

4. METHODS

Air mass types classification

In this preliminary study, only winter was considered because this season possesses, such as autumn, the highest mean MI admission rates.

Statistical analyses were performed by using two software: SPSS for Windows version 11.0 and XLSTAT version 7.1.

The Principal Component Analysis (PCA) and the Agglomerative Hierarchical Clustering (AHC) were used in succession to identify groups of days for which the covariant behaviour of meteorological variables were similar (McGregor and Bamzelis, 1995). The seven meteorological parameters recorded at 0900 and 1500 hours were used as input variables into the PCA. All days which showed in both hours a wind velocity value lower than 0.2 $m \cdot s^{-1}$ were considered as calm days and the wind direction was excluded by the assessment.

In order to describe and to classify each winter general synoptic scale situation characterizing each air mass type, mean values of daily original meteorological variables were calculated.

Relationships with myocardial infarction admissions

A multiyear comparison of MI admissions among air mass types was made by the calculation of a myocardial infarction admission index (MIAI), that is represented by the ratio of the daily admission for MI to the average in a specific winter expressed as percentage.

Sequences of air mass types were also investigated and each possible 2-day, 3-day and 4-day air mass type combination was analysed. Sequences producing above average MIAI (MIAI > 100) on the last day of the sequence were then identified.

Air mass types and their sequences were then tested for MIAI differences using analysis of variance (ANOVA) and Least Significant Difference (LSD) tests.

5. RESULTS

Air mass types classification

Four principal components which accounted for 74.2% of the variance in the original meteorological data were identified and than, through the AHC, five air mass types were obtained. Synoptic weather charts representative of the general synoptic scale situation for each air mass type are shown in Fig. 1a-d (source www.metoffice.com). Only for the air mass type 5, characterized by mix conditions, and therefore not easily attributable to a specific synoptic situations, the weather chart is not shown.

1. Air mass type 1 - Anticyclonic polar continental

Characterized by simultaneous presence of an anticyclonic centre over northern and central part of Europe and a cyclonic centre over Balkans and central Mediterranean sea (Fig 1a). The atmospheric pressures are medium/high but some variations among days exist. Winds are predominantly north-easterly, relatively dry, and conditions are typically cold. Cloud cover is generally low.

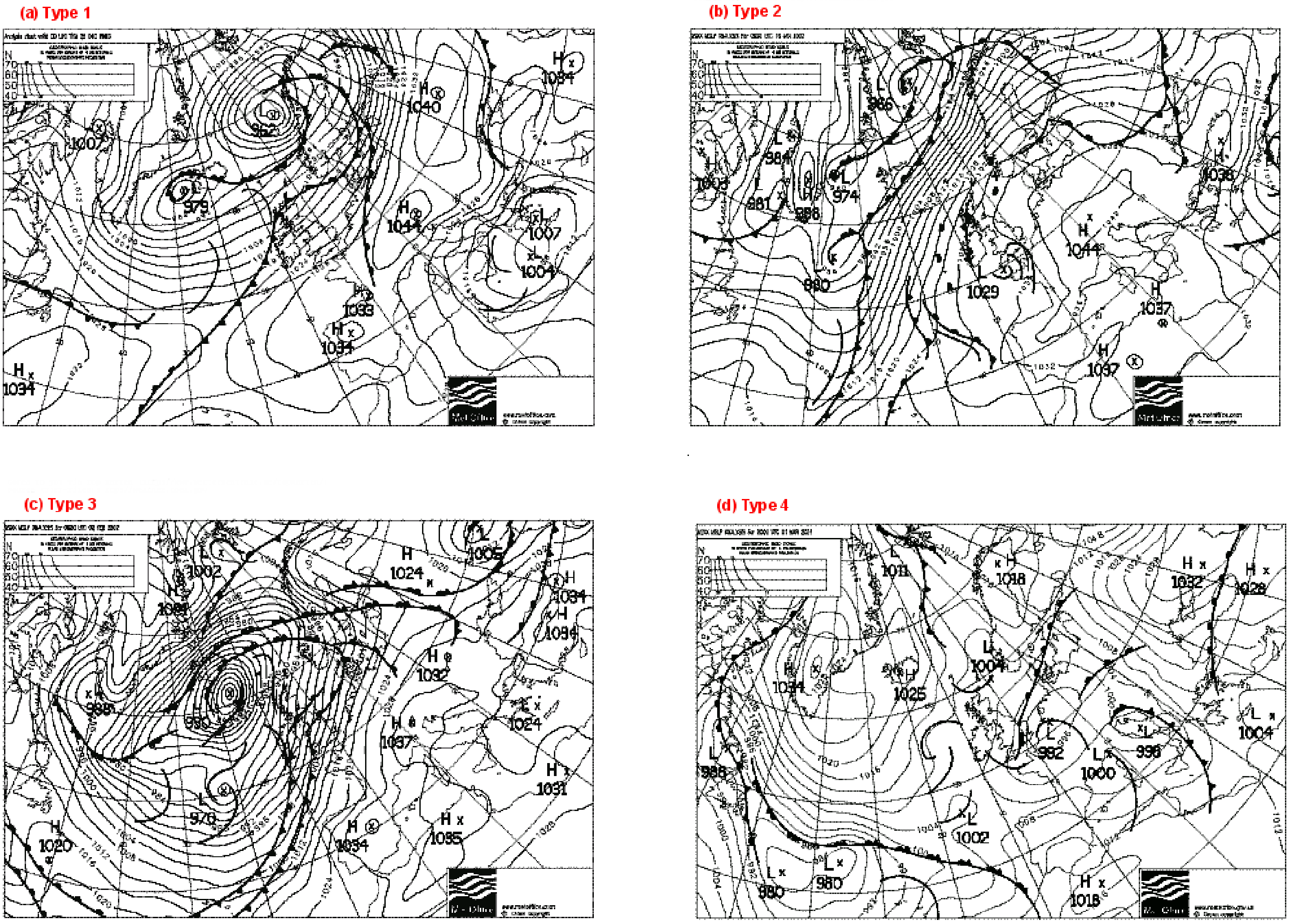

Fig. 1 Representative synoptic charts for the four winter air mass types: (a) 1 - Anticyclonic polar continental; (b) 2 - Continental anticyclonic; (c) 3 - Anticyclonic mixed tropical maritime and continental; (d) 4 - Cyclonic.

2. Air mass type 2 - Continental anticyclonic

A well developed anticyclonic system dominates the central Mediterranean sea having its centre on central Europe (Fig. 1b). Such synoptic situation is characterized by high atmospheric pressures, low air circulation (mainly easterly and north-easterly) and calm conditions. Humidity levels are generally medium/low at the beginning of the situation, but progressively increase day by day, particularly night time when haze and fog can also occur. The sky is generally clear and air temperatures are very low, reaching the lowest values among all air mass types.

3. Air mass type 3 - Anticyclonic mixed tropical maritime and continental

A well developed anticyclonic system dominates the central Mediterranean sea having its centre on northern Africa or eastern Mediterranean sea (Fig. 1c). Generally this conditions can be the results of the development of an anticyclonic gloom over northern Africa, or sometimes the possible evolution in time of the synoptic situation described for the air mass type 2. Such situation is characterized by high atmospheric pressures, calm or low wind with a prevalent south-westerly component. Cloud cover is generally low and humidity levels medium/low due to warm air circulation. This air mass type includes the days with the highest maximum air temperature between the different air mass typology, even if those minimum are very low.

4. Air mass type 4 - Cyclonic

Such air mass type is generally associated with frontal passages which often induce the formation of a cyclonic system centred on central Mediterranean sea (Fig. 1d) which induces the lowest atmospheric pressure values between the different air mass types. The wind is mainly weak with a predominantly southerly component, but in connection with frontal passages it can temporary increase up to strong intensity. Cloud cover and humidity levels are high and air temperatures are mild.

5. Air mass type 5 - Mixed

This air mass type includes all situations characterized by low pressure gradient and it is not easily attributable to specific synoptic conditions such as the previous mentioned air mass types. However days included in this air mass type are generally characterized by medium/high levelled atmospheric pressure over central Mediterranean, low air circulation and sometimes by the passages of weak fronts. These days experience weak wind, or calm situations, and high levels of cloud cover due to the passages of weak fronts or to the formation of low clouds as a consequence of high humidity levels which, together with air mass type 4, are the highest. Air temperatures are close to the ones of the air mass type 4.

The air mass type 5 showed the maximum frequency, while the minimum was observed for the air mass type 2 (Table 1). In particular, in the winter 2000-2001 only one day (1.1%) with air mass type 2 occurred.

WINTER	AIR MASS TYPES				
	1	2	3	4	5
1998-1999	20.0	17.8	21.1	21.1	20.0
1999-2000	8.8	13.2	24.2	17.5	36.3
2000-2001	22.2	1.1	18.9	15.6	42.2
2001-2002	13.3	18.9	16.7	7.8	43.3
2002-2003	32.2	6.7	13.3	23.3	24.5
All winters	19.3	11.5	18.8	17.1	33.3

Table 1: Inter-annual variability (%) of air mass frequency during winters.

Re*lationships with myocardial infarction admissions*

Results concerning the multiyear comparison of mean daily admissions for MI between air mass types are shown in the table 2. Observing the last column on the right it is clearly evident the increasing trend in mean admission rate over the five studied winters. This linear increase was statistically significant (r = 0.94, P < 0.01).

Only the air mass type 3 and 4 showed a positive mean departures, although there was some inter-annual variability of admission rate. In particular for the air mass type 3 only one winter (1999-2000) showed a negative departure. Indeed, the air mass type 4 showed a greater variability, with the highest positive departure during the winter 2000-2001, compared to the other winters, but also two very low negative departures. The lowest negative departure was observed for the air mass type 2 during the winter 2000-2001, but this value is quite anomalous. In fact, in all the other winters, this air mass, that is the coldest one, showed positive departure values. The anomalous situation occurred during the winter 2000-2001 is attributable to the exceptionally low frequency of occurrence of days characterized by air mass type 2 (Table 2).

WINTER	AIR MASS TYPES					
	1	2	3	4	5	Mean
1998-1999	1.39 (0.10)	1.75 (0.46)	1.32 (0.02)	0.84 (-0.45)	1.17 (-0.13)	1.29
1999-2000	1.13 (-0.40)	1.58 (0.06)	1.41 (-0.12)	2.06 (0.54)	1.45 (-0.07)	1.53
2000-2001	1.95 (0.39)	0.00 (-1.56)	1.71 (0.14)	2.43 (0.86)	1.74 (0.17)	1.56
2001-2002	2.08 (0.19)	2.00 (0.11)	2.13 (0.24)	1.43 (-0.46)	1.82 (-0.07)	1.89
2002-2003	2.10 (-0.38)	2.67 (0.19)	2.92 (0.44)	2.71 (0.23)	2.00 (-0.48)	2.48
Mean departure	-0.02	-0.15	0.14	0.14	-0.12	

Table 2: Mean daily admissions for myocardial infarction by air mass type. In brackets are indicated the departure values from the winter mean.

Excluding this negative value, the mean departure of this air mass is the highest (0.20) observed among the air mass types. Regarding the air mass type 1, even in this case an inter-annual variability was observed and a prevalence of positive departures were found. On the other hand prevalent negative values were observed for the air mass type 5, with the only exception of the winter 2000-2001.

Considering MIAI, the ANOVA and the LSD tests did not show significant differences among the 5 air mass types over the five studied winters, even if a significant difference was found considering winters individually. Winter 1998-1999 revealed that the air mass type 2 was significantly different (P < 0.01) to the air mass type 4.

Significant differences were also found considering the persistence of the same air mass type. The sequences of the air mass type 2 showed to be significantly different to the air mass type 5 (P < 0.05), both considering 2-day and 3-day combination. The highest MIAI value was reached for persistent days with the air mass type 2, followed by the type 3 and 4. On the other hand, persistent days with the air mass type 1 and 5 showed below average MIAI (MIAI < 100).

Figure 2 shows that for all possible 3-day sequences, the most frequently combinations were 444, 222 and 333. Among the sequences with very high mean last day MIAI (MIAI ≥ 200), sequences possessing the air mass type 3 occur more frequently, while sequences possessing the air mass 5 showed the lowest frequency. The same occurred considering sequences for 2-day and 4-day.

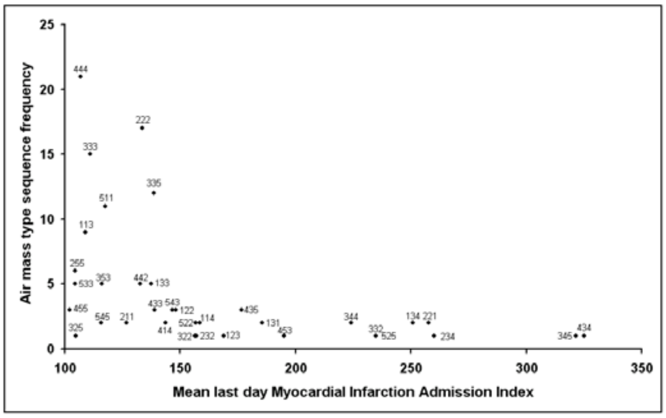

Fig. 2: Three-day air mass sequences vs. myocardial infarction admission above average.

6. CONCLUSIONS

Two antyciclonic air mass types (continental anticyclonic and anticyclonic mixed tropical maritime and continental) and the cyclonic air mass, were often associated with high mean daily admissions for myocardial infarction, both considering all winters together or taking into consideration each winter individually.

These results were also confirmed taking into account the sequences of air mass types. Especially the persistence of anticyclonic air mass types, characterized by very low air temperature (even if the maximum temperature can be relatively high) and with high daily temperature range, caused by clear sky and absence or weak wind, was related to a strong increase in hospitalizations. On the other hand, combination of days with the mixed air mass type, characterized by low pressure gradient, calm situations, high levels of cloud cover and therefore low daily temperature range, were always associated with a number of hospital admissions for myocardial infarction below the winter average.

Few studies on the relationships between air mass types and hospitalizations for MI were performed so far, while few experiences concerned mortality events, such as a recent study carried out in Birmingham (McGregor, 2001), UK. It deals the relationships between atmospheric circulation variables and mortality for ischaemic heart disease. This study evidenced that especially blustery westerly flows and rapidly changing weather from the west, or climatologically strong northeasterly to southeasterly flows of cold air, which bring rapidly changing and anomalous thermal conditions to the study area, were statistically associated to an increase of mortality events.

Future development will be the association of air mass types with air quality variables, such as air pollution, and the consequent impact on specific pathologies. This study will be also extended to other seasons and other pathologies.

The approach based on the air mass types classification showed interesting relationships with myocardial infarction admissions. These results should encourage the development of a synoptic climatological model which could be used for an operative weather watch/warning system, informing and eventually alerting people at high risk and improving hospital assistance when weather discomfort conditions are forecast.

7. ACKNOWLEDGEMENTS

The authors wish to thank Dr G. Pasquini and Mr S. Sinatti of A.O.C.-Firenze (Azienda Ospedaliera di Careggi) for providing hospital admission data; Mr F. Sabatini (IBIMET-CNR) for providing meteorological data.

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