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Association of monthly frequencies of diverse diseases in the calls to the public emergency service of the city of Buenos Aires during 1999–2004 with meteorological variables and seasons

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Abstract This work aims to study associations between monthly averages of meteorological variables and monthly frequencies of diverse diseases in the calls to the public ambulance emergency service of the city of Buenos Aires during the years 1999–2004. Throughout this time period no changes were made in the classification codes of the illnesses. Heart disease, arrhythmia, heart failure, cardiopulmonary arrest, angina pectoris, psychiatric diseases, stroke, transient ischemic attack, syncope and the total number of calls were analyzed against 11 weather variables and the four seasons. All illnesses exhibited some seasonal behavior, except cardiorespiratory arrest and angina pectoris. The largest frequencies of illnesses that exhibited some association with the meteorological variables used to occur in winter, except the psychiatric cases. Heart failure, stroke, psychiatric diseases and the total number of calls showed significant correlations with the 11 meteorological variables considered, and the largest indices (absolute values above 0.6) were found for the former two pathologies. On the other side, cardiorespiratory arrest and angina pectoris revealed no significant correlations and nearly null indices. Variables associated with temperature were the meteorological proxies with the largest correlations against diseases. Pressure and humidity mostly exhibited positive correlations, which is the opposite of variables related to temperature. Contrary to all other diseases, psychiatric pathologies showed a clear predominance of positive correlations. Finally, the association degree of the medical dataset with recurrent patterns was further evaluated through Fourier analysis, to assess the presence of statistically significant behavior. In the Northern Hemisphere high morbidity and mortality rates in December are usually assigned to diverse factors in relation to the holidays, but such an effect is not observed in the present analysis. There seems to be no clearly preferred meteorological proxy among the different types of temperatures used. It is shown that the amount of occurrences depends mainly on season rather on its strength quantified by temperature.

Keywords Diseases · Climate · Seasonal behavior · Emergency service

Introduction

Despite the abundance of studies, the detailed mechanisms by which environmental influences exert biological effects on humans remain to be clarified, possibly because of the simultaneous change of many ambient variables and the complex relationship between environment and biology. However, the importance of the detection of consistent seasonal behavior relies on the possibility of anticipating situations, which may allow to plan and implement actions leading to an improvement of medical care services. Moreover, extended range health forecasts could be developed from the output of seasonal climate prediction models. After the determination of a threshold that merits a warning trigger for the allocation of specific resources, this could become a useful tool for emergency services and hospital authorities. It is already well-known since a long time that the diseases exhibit a seasonal feature with maximum frequencies during different year epochs that depend on each pathology (Keatinge et al. 1989; Seto et al. 1998; Gemmell et al. 2000). Notwithstanding some discrepancies or even contradictions (see e.g. Giua et al. 2010) among diverse

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sampled populations, the incidence of many diseases exhibits a winter peak and summer trough in diverse regions of the world (Pell and Cobbe 1999; Nakaji et al. 2004). Also, the importance of studies related to meteorology has grown in recent years after the general concern on climatic change. Many works on this subject refer to the interaction in the variation of weather conditions and human health. However, the general problem of the interplay between meteorology and health is quite complex and this kind of analyses can hardly if at all isolate the effect on the statistics of diseases of a variety of other influences, among them socioeconomic, nutrition and ambient factors. Therefore, extreme care must be exerted in giving a global meaning to local studies, where rather homogeneous extra-climatic conditions might exist.

Many studies performed in different cities around the world have statistically shown that a relevant part of the seasonal behavior of pathologies is related to weather conditions (Auliciems and Frost 1989; Auliciems and Skinner 1989; González et al. 2001; Bartková 2003). Diverse kinds of diseases have been considered, as cardiac (Mc Gregor 2001; Ebi et al. 2004; Mc Gregor 2005), respiratory (Moolgavkar et al. 1997) or a variety (van Rossum et al. 2001). Some of these studies were related to mortality (Becker and Weng 1998; Dessai 2002; Davis et al. 2003), while others referred to emergency services of private or public systems (Ohshige et al. 2006; Liang et al. 2008). Sometimes the sampling volume limits any generalization. Possibly due to the lack of the required statistical medical information, the seasonality of diverse pathologies in the Southern Hemisphere has not been so systematically studied as in the Northern Hemisphere. In Argentina, for example, some specific results for emergencies during a year in a hospital in Buenos Aires have been presented by Rusticucci et al. (2002). In this city there has been a lack of reliable health datasets all over the city, but in recent years the authorities have been trying to overcome some aspects of this problem.

This work uses information from the public ambulance emergency service of the city of Buenos Aires called SAME (Sistema de atención médica de emergencias), related to the monthly frequency of occurrence of diverse diseases as diagnosed by the corresponding physicians. The whole city is covered, which allows to assume a significant generalization degree. Here the four seasons exhibit definite environmental and lifestyle characteristics and there are very clear differences among them. The present study is conducted in a small geographic area (202 km^2) and is therefore optimal to try to define clearly different seasonality related factors. The aim of the study was to analyze the correlation between meteorological variables and the frequency of occurrence of diverse diseases from the telephone calls to the public ambulance emergency service of the city of Buenos Aires during the years 1999–2004, as no changes were made in the classification codes of the illnesses during that time. The significance of seasonality of the diverse diseases becomes assessed. In addition, winter and summer emergency calls averages are compared. The year epochs with the largest frequencies of the considered diseases are also determined.

Data and methods

The medical dataset provided by SAME contained the monthly frequencies for the period 1999–2004 (72 months) of selected diseases among the categories used to classify the diagnostics made by the service physicians. The considered codes corresponded to ischemic heart disease (IHD), arrhythmia (A), heart failure (HF), cardiopulmonary arrest (CA), angina pectoris (AP), psychiatric diseases (PD), stroke (CVA), transient ischemic attack (TIA), syncope (S) and the total number of calls to SAME (T). There are 52 categories that aim to classify every case met by the city service with a code. The list is not based on the international classification of diseases (ICD), but it has rather evolved on the experience of the working physicians. Therefore, there is no exact correspondence for every pathology between the city codes and the ICD. During the considered time period the city classification codes for diseases remained without changes. The monthly medical record was adjusted to 30 days in order to be able to compare equal periods (Spiegel and Stephens 1998). The time series were de-trended, as statistically significant linear long-term tendencies were found. De-trending may separate non-climatic confounders (if these do not exhibit some kind of tendency).

Buenos Aires is a mid-latitude city in the Southern Hemisphere which has a humid subtropical climate with four distinct seasons and an annual mean temperature above 17 °C. The warmest month is January, with a daily average around 25 °C. Heat waves from the north can bring temperatures above 35 °C, yet the city may also be subject to cold fronts. Relative humidity is moderately high (around 65 %) during summer. Spring and autumn are generally mild and volatile, with average temperatures around 17 °C. Winters are temperate and there is frost only a few times per year. Relative humidity averages almost 80 %, with moderate to heavy fogs during autumn and winter. July is the coldest month, with an average mean temperature of almost 11 °C. Southerly winds may keep temperatures below 10 °C for a few days, whereas winds from the north may bring temperatures above 20 °C. Spring is very variable, there may be heat waves with temperatures of 35 °C even in early October, as well as periods of much colder weather with highs close to 10 °C. Frost has occurred as late as November, although this is unusual. Precipitation typically exceeds 1000 mm per year. Showers can be expected at any season and hailstorms may occur.

A descriptive analysis was first performed. The year in Buenos Aires was divided into summer (December, January and February), autumn (March, April and May), winter (June, July and August) and spring (September, October and November), whereby seasonal frequency monthly means were calculated in order to evaluate if there are epochs with higher occurrences. A paired *t* test was performed for the winter and summer mean differences of each disease (Spiegel and Stephens 1998). We examined the null hypothesis that the amount of emergency requests were equal.

The meteorological monthly data in the period 1999–2004 were obtained in the local city airport (34.56 S; 58.41 W). The following variables were considered: city level atmospheric pressure (P), mean temperature (Tm), maximum temperature (Tmax), minimum temperature (Tmin), maximum apparent temperature (Ta), minimum wind chill temperature (Tw), accumulated precipitation (Pp), relative humidity (H), total heating degree days (HDD) and total cooling degree days (CDD). We derived thermal amplitude as Tmm = Tmax – Tmin. Apparent temperature is an equivalent temperature that measures the degree of human discomfort due to combined heat and humidity. It is based on studies of human physiology and textile (clothing) science. The apparent temperature is designed so that it exceeds the air temperature when humidity is relatively high. The apparent temperature does not consider the effects of air movement (wind speed) or exposure to sunshine. Wind chill is an equivalent temperature that measures the degree of physical discomfort and stress from combined cold and wind. It was developed from physiological studies of the rate of heat loss for various combinations of ambient temperature and wind speed. The wind chill equals the air temperature when the wind speed is 4 miles per hour or less. At higher wind speeds, the wind chill is lower than the air temperature and measures the increased rate of heat loss from the body under windy conditions. As stated, apparent and wind chill temperatures have an impact only when they reach certain values, which was the criterion used in the calculations for each day, only thereafter monthly averages were obtained. A heating degree day is an index used to quantify the amount of heating required for houses or businesses for a given day. Heating degree days for a given period are the summations of negative differences between the mean daily temperature (F) and the base temperature of 65 F for that period. The heating year extends from July 1 to June 30. A cooling degree day is an index used to quantify the amount of cooling required for houses or businesses for a given day. Cooling degree days for a given period are the summations of positive differences between the mean daily temperature (F) and the base temperature of 65 F for that period. The cooling year extends from January 1 to December 31. Formulas and tables for the above definitions may be found, for example, at the US National Weather Service site (www.weather.gov).

All variables were subject to normal distribution analyses through a Kolmogorov-Smirnov test, chi-squared and normal probability plots (Hair et al. 1995), and it was found that they suited that behavior. Variance homogeneity was also checked through an F test (Spiegel and Stephens 1998). Fits to a linear model for the relations between variables were also evaluated. Correlation analysis was performed to assess the associations between meteorological and medical data. The Pearson coefficient *r* was used to calculate the linear correlation. In order to evaluate the statistical significance of the relations, the coefficient values were subject to hypothesis test. A *t* test with the null hypothesis $r=0$ was performed.

Time series analyses furnish information on the way in which potential causes and observed effects evolve, whether they operate uniformly over the studied interval or exhibit some definite patterns. This study also employed these techniques to assess the presence of statistically significant seasonality, its strength and the predictability of the time series. After eliminating any trend the time series was assumed to consist of seasonal and random components, where the former contribution was extracted by Fourier analysis.

Results

During the 1999–2004 time period there were over 1 million emergency calls received by SAME. Table 1 shows the total number and monthly average, maximum and minimum per disease over the whole period. Among all diseases chosen for this work, PD exhibited the largest total value and

Table 1 Total and monthly average, maximum and minimum values for each disease and the total number of calls over the 1999–2004 period

Disease	Total number of cases over 6 years	Monthly average (minimum, maximum) number of cases over 6 years
IHD	11,528	160.1 (91, 217)
A	9,794	136.0 (89, 190)
HF	6,385	88.7 (42, 177)
PD	80,724	1,121.2 (877, 1426)
CVA	13,066	181.5 (122, 260)
TIA	2,360	32.8 (13, 63)
CA	1,206	16.8 (4, 34)
S	2,551	35.4 (7, 83)
AP	16,358	227.2 (134, 320)
T	1,094,840	15,206.1 (11270, 18439)

IHD ischemic heart disease, *A* arrhythmia, *HF* heart failure, *PD* psychiatric diseases, *CVA* stroke, *TIA* transient ischemic attack, *CA* cardiopulmonary arrest, *S* syncope, *AP* angina pectoris, *T* total number of calls to SAME monthly average. This emergency service code encompasses nervous crises, anxieties, neuroses and psychoses. CVA and TIA were considered separately and both components had different behavior. Among the analyzed cardiovascular diseases, which are IHD, A, HF, S and AP, the last one exhibited the largest numbers. Cardiorespiratory arrest had the lowest values among all pathologies. The evolution in time for all categories may be seen in Fig. 1.

There is a clear tendency for increasing requests to SAME over time which may be seen in Fig. 1. An exceptional local maximum of total cases may be observed in July 1999 (Fig. 1), which is not only remarkable by its value but also because it supplants June as the yearly peak month. From here on we will work with the linearly de-trended curves. We calculated the seasonal monthly averages and standard deviations over the 6 years and assessed the significance of seasonality (see Table 2). A paired *t*-test ($\alpha = 0.05$) was performed for the comparison between summer and winter means. All differences were found to be significant, except for CA and AP. The latter two diseases exhibited non-significant differences between monthly means of any pair of seasons. IHD exhibited a maximum during spring instead of winter, but the difference between both means was statistically non-significant. PD showed a maximum during summer and minimum in winter, which is the opposite of most diseases.

The evolution in time of all considered meteorological parameters may be seen in Fig. 2. Correlation indices between monthly averages of meteorological variables and monthly frequency of diseases are shown in Table 3. Variables related

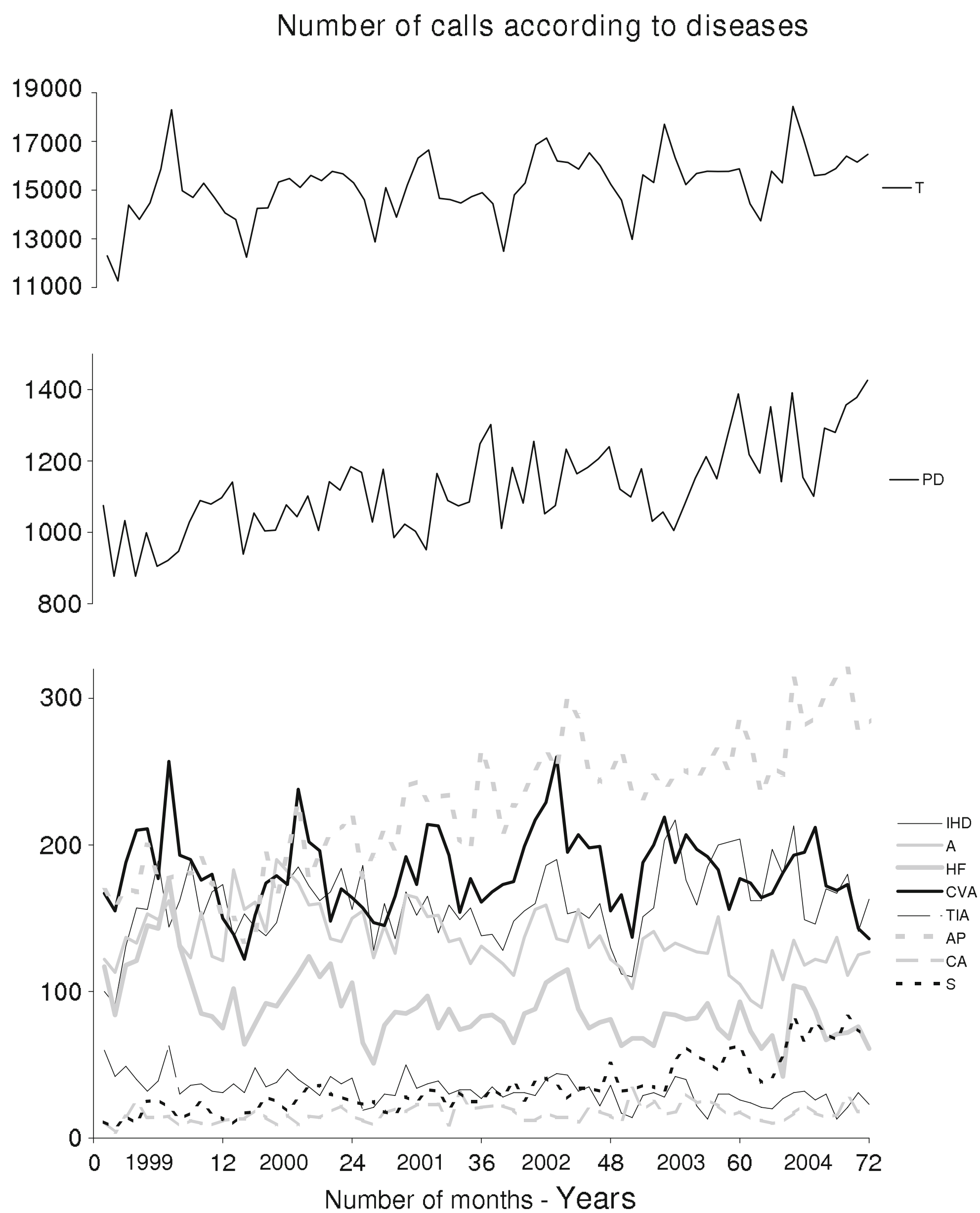

Fig. 1 The time evolution of the monthly number of diseases and the total number of calls for years 1999–2004

Table 2 Monthly means and standard deviations (respectively above and below) per season for all diseases and the total number of calls. Statistically significant differences between winter and summer means at the 0.05 level of a paired *t* test are represented with boldface

Season	IHD	A	HF	PD	CVA	TIA	CA	S	AP	T
Summer	**129.8**	**137.5**	**91.4**	**1050.8**	**155.7**	**36.1**	13.0	**13.5**	173.2	**13295.1**
	25.6	**18.7**	**14.3**	**74.7**	**15.0**	**8.5**	**6.5**	**8.1**	**26.2**	**754.8**
Autumn	**145.7**	**150.0**	**98.0**	**985.2**	**182.3**	**39.5**	**13.6**	**14.7**	**172.7**	**14391.4**
	17.2	**16.2**	**18.6**	**87.5**	**21.0**	**5.8**	**5.0**	**10.5**	**23.2**	**894.3**
Winter	**151.9**	**155.2**	**116.7**	**946.3**	**200.6**	**44.2**	14.7	**21.6**	187.5	**15009.1**
	22.4	**14.9**	**20.9**	**72.8**	**24.9**	**7.7**	**5.0**	**10.6**	**21.7**	**1048.4**
Spring	**152.2**	**146.9**	**99.6**	**1040.7**	**176.1**	**37.0**	**14.8**	**20.0**	**185.7**	**14653.3**
	18.9	**14.1**	**11.3**	**62.5**	**19.3**	**5.8**	**5.8**	**11.6**	**23.0**	**473.8**

IHD ischemic heart disease, *A* arrhythmia, *HF* heart failure, *PD* psychiatric diseases, *CVA* stroke, *TIA* transient ischemic attack, *CA* cardiopulmonary arrest, *S* syncope, *AP* angina pectoris, *T* total number of calls to SAME

to temperature and also pressure exhibit the largest values and amounts of statistically significant associations. Most parameters exhibit many significant correlations, but CA, AP and S show one or null significant indices. Recall that AP and CA showed a lack of seasonality. HF, PD, CVA and T exhibit significant correlations with all meteorological variables, but the largest absolute values of indices are for HF and CVA (above 0.6). A distinct characteristic for PD is that the correlation index sign for this pathology is usually opposite to all others against each meteorological variable. Both stroke categories exhibit different characteristics. TIA leads to indices around 0.3, whereas most CVA correlations are the highest ones, close to 0.6.

We performed a Fourier analysis of the medical time series and we found out that the amplitudes associated with annual and semiannual cycles mostly exceeded any other periodic behavior. However, the intensity of the oscillations lean on much larger averages. Large amplitudes around 0.4 1/month (period 2.5 months) in some diseases were probably due to the aliasing effect of larger frequencies (Bendat and Piersol 1971). Only IHD, A and T exhibit both significant annual and semi-annual behavior. HF, PD, CVA and TIA exhibit a dominant yearly pattern, whereas AP and S show a slight semi-annual feature. On the contrary, from CA no clear signature can be extracted. There are also some indications of seasonal (3 months) behavior, most clearly for IHD.

We also carried out a Fourier analysis of the meteorological parameters. It revealed that all of them are strongly dominated by the yearly cycle. In addition, it showed that HDD, H and P typically peak during winter and are about 180° out of phase with the remaining variables. In order to assess the representativeness of the meteorological parameters for the conditions within each month, we exhibit in Table 4 the average standard deviations σ_P and σ_T over the years 1999–2004 for air pressure at the city level (P) and mean temperature (Tm), respectively. Studies with daily data assume a short term effect, whereas monthly information allows to better capture the accumulative effect of a persistent condition. However, detailed mechanisms between monthly meteorology and number of diseases may at the present time rather be of a speculative nature, as it is also often the case for shorter time scales (see the Introduction and Discussion sections).

Discussion

The above results exhibit many similarities but also some particular aspects with respect to previous studies in Buenos Aires and other large cities or areas (see e.g. Rogot et al. 1976; Rusticucci et al. 2002; Nakaji et al. 2004). A clear seasonality pattern emerged in this work, where the highest rates were generally observed in winter and the lowest in summer. The yearly peaks usually correspond to June, which is slightly warmer than July, both of which are the coldest months of the year. It is particularly well known that major infectious and respiratory diseases are epidemic in winter and heart diseases and cerebral stroke are known to peak in the same period according to studies developed in different world areas (see e.g. Rogot et al. 1976; Sakamoto-Momiyama 1978; Nakaji et al 2004). Many biological causes are attributed to the behavior of the latter two pathologies, like seasonal variations of blood pressure, cholesterol and triglicerids levels, but mainly plasmatic fibrinogen and blood viscosity values, all highest in winter (see e.g. Wang et al. 2003). In the Northern Hemisphere high morbidity and mortality rates in December are usually assigned to increased food and alcohol consumption and emotional and psychological stresses around the holidays (Kloner et al. 1999; Phillips et al. 2004), but such an effect may not be inferred in the present analysis. Total winter emergencies exceed those of summer by 13.1 %. Results by Rusticucci et al. (2002) found that winter emergencies

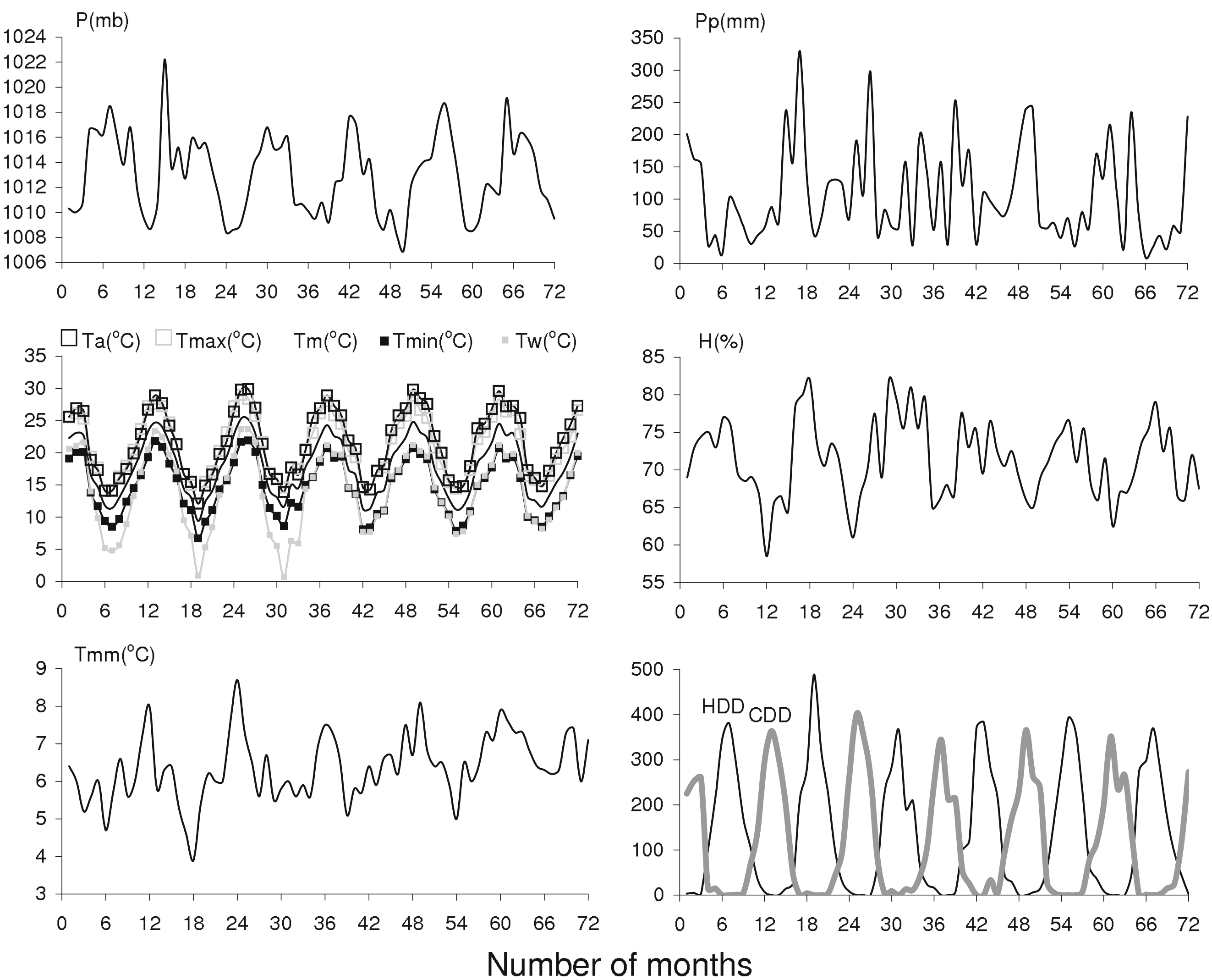

Fig. 2 The time evolution of the meteorological variables during the years 1999–2004

exceeded those of summer by 16.7 % in the year and hospital of their study in Buenos Aires.

The general reasons for the observed behavior of occurrences may be attributed to seasonal variations of biological body parameters, air pollution, sunlight, diet, but variation in temperature has been generally considered the most likely reason. However, the number of requests and temperature exhibit a significant correlation along the year but not within each season individually (all correlation indices were below 0.35, not shown for brevity). This means for example, that a summer that is hotter than a previous one will not directly lead to more PD cases. Then, the amount of occurrences may depend mainly on season rather than on its strength quantified by temperature. Diseases with a large amount of significant correlations may be following a pattern linked to the seasonal behavior of meteorological variables, whereas pathologies with a few statistically significant indices may be indicative of associations just by chance. According to the Fourier analysis the monthly number of requests generally contains two periodic significant groups: diseases with annual (0.08 1/month) or semiannual (0.17 1/month) frequencies (the rest may be mainly due to other periods or with steady or random occurrences along the year).

There are some limitations in the present analysis. The results shown in this study may partially reflect the influence of weather on use of the city public ambulance service rather than on each individual disease incidence. In addition, patient illness was coded on the basis of the first diagnosis by doctors in the ambulance, which may have differed from the final diagnoses. In addition, when the emergency service was not able to clearly distinguish between different diseases that show the same symptoms at first and could only be determined later after further examinations, the classification relied on the experience of the physician. However, miscoding by either reason is deemed to occur

Table 3 Correlation coefficients among medical and meteorological variables. Statistically significant values at the 0.05 level are shown in boldface

Variables	IHD	A	HF	PD	CVA	TIA	CA	S	AP	T
P	**0.401**	**0.350**	**0.457**	**−0.369**	**0.508**	**0.386**	0.042	0.199	−0.029	**0.453**
Tm	**−0.494**	**−0.371**	**−0.623**	**0.465**	**−0.648**	**−0.413**	−0.013	−0.167	−0.026	**−0.581**
Tmax	**−0.482**	**−0.387**	**−0.622**	**0.476**	**−0.645**	**−0.420**	−0.025	−0.165	−0.018	**−0.579**
Tmin	**−0.500**	**−0.351**	**−0.620**	**0.452**	**−0.650**	**−0.403**	−0.002	−0.168	−0.035	**−0.579**
Tmm	−0.149	**−0.370**	**−0.314**	**0.357**	**−0.293**	**−0.293**	−0.124	−0.063	0.076	**−0.285**
Ta	**−0.492**	**−0.362**	**−0.598**	**0.444**	**−0.611**	**−0.403**	−0.013	−0.185	−0.031	**−0.574**
Tw	**−0.484**	**−0.348**	**−0.571**	**0.419**	**−0.630**	**−0.352**	−0.009	−0.173	−0.071	**−0.578**
Pp	**−0.445**	−0.108	**−0.345**	**0.234**	**−0.310**	−0.101	0.080	−0.028	0.026	**−0.242**
H	0.124	**0.353**	**0.356**	**−0.399**	**0.416**	**0.343**	0.158	0.031	0.012	**0.339**
HDD	**0.427**	**0.394**	**0.567**	**−0.396**	**0.581**	**0.340**	−0.049	**0.251**	0.105	**0.563**
CDD	**−0.487**	**−0.294**	**−0.595**	**0.487**	**−0.654**	**−0.437**	−0.089	−0.063	0.051	**−0.518**

IHD ischemic heart disease, *A* arrhythmia, *HF* heart failure, *PD* psychiatric diseases, *CVA* stroke, *TIA* transient ischemic attack, *CA* cardiopulmonary arrest, *S* syncope, *AP* angina pectoris, *T* total number of calls to SAME

independently from weather conditions. Another shortcoming of this work is the availability of only the monthly number of calls instead of daily or weekly values. Nevertheless, some of the diseases could not be analyzed with daily or weekly figures because they would have very low statistical significance.

Conclusions

This work tried to find links on a monthly scale between meteorological variables and the frequency of selected diseases in the calls to the public emergency service of the city of Buenos Aires during the years 1999–2004, when the classification codes of the illnesses remained without changes. A large number of significant correlations were found and some even exceeded 0.6. For all pathologies that exhibited some association with meteorological variables, monthly frequency maxima were observed during winter, except PD, that attained their highest values in summer. Moreover, there are negative correlation indices between most diseases and the diverse variables linked to temperature and positive values with atmospheric pressure and humidity. Contrary to all other pathologies, PD showed a clear predominance of positive correlations. CVA, IHD, AP and HF have already been extensively analyzed in previous works in relation to meteorological factors with similar results to the present ones (see references in the Introduction and citations therein). Lack of association of CA with meteorological variables was found, which may be due to the diverse causes that may lead to it (respiratory, oncological, cardiac). CA is, among all medical variables, the one that exhibits less clearly a pattern associated with season or weather. There seems to be no clearly preferred meteorological proxy for the prediction of the amount of diseases among the pressure and the different types of temperatures used. In the Northern Hemisphere high morbidity and mortality rates in December are usually assigned to diverse factors in relation to the holidays, but such an effect is not observed in the present analysis. It is shown that the amount of occurrences may depend mainly on season rather than on its strength quantified by temperature. It is found that the recurrent component of the number of requests may be mainly reproduced with two significant groups: diseases with annual and semiannual periodicity, which are not in phase.

Table 4 Monthly standard deviations calculated with daily data of mean temperature (Tm) and air pressure at city level (P) averaged over the years 1999–2004

Month	σ_P (mb)	σ_T (°C)
January	4.1	3.5
February	4.8	4.2
March	4.4	5.1
April	5.3	3.0
May	5.2	2.9
June	5.7	3.3
July	5.6	2.7
August	4.3	3.0
September	6.9	4.7
October	5.0	4.0
November	3.5	4.8
December	4.0	5.5

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