Research article

Weather conditions and Bell's palsy: five-year study and review of the literature

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Abstract

Background: Climatic or meteorological condition changes have been implicated in the pathogenesis of Bell's palsy (BP). We evaluate the influence of meteorological parameters, such as temperature, humidity, and atmospheric pressure, and their variation and covariation on the incidence of BP and present a review of the literature on the effect of meteorological conditions on facial nerve function.

Methods: A total of 171 cases of BP admitted to our Department over a five-year period were studied. The meteorological database included daily values of 13 distinct parameters recorded at the meteorological station of the University of Ioannina during this period. A relationship between each meteorological variable and the incidence of BP was investigated by applying (X^2) test on data from 13 contingency tables. In addition, the influence of different weather types on the incidence of BP was also investigated. For this purpose Cluster Analysis was used to create eight clusters (weather types) for the Ioannina prefecture and (X^2) test was applied on the contingency tables consisting of the days of BP cases for each cluster.

Results: No significant correlation was found either between BP and each distinct meteorological parameter or between BP and any specific weather.

Conclusions: Meteorological conditions, such as those dominating in the Northwestern Greece, and/or their changes have little effect on the incidence of BP. Multicenter studies taking into account atmospheric pollution, and climatic differences between countries, are necessary to scrutinize the environmental effects on facial nerve function.

Background

Idiopathic peripheral facial nerve paralysis, or Bell's palsy (BP), is the most common cause of facial nerve palsy. BP accounts for approximately 49% to 51% of all cases, with an estimated incidence of 13 to 34 cases per 100,000 people per year [1]. A variety of theories have been proposed with regard to its etiology, including viral infection, vascular dysfunction, disorder of the autonomic regulation and inflammation [2].

Climatic or meteorological factors, such as temperature, humidity, or barometric pressure have been implicated in triggering off the pathogenetic mechanism of BP. It has been suggested that a meticulous study of a "combination of changing factors" may help illuminate the underlying pathophysiology of this "puzzling" disease [3]. The seasonal distribution of the disease has been extensively studied [4–14]. However, no consensus has been reached. Patients often recall cooling of the face or a cold draught just before the outburst of the facial palsy. BP following airplane trips has also been reported [3]. Experimental data support a hypothesis of low temperatures in the pathogenesis of BP [15–18].

In the present study, we evaluated the influence of meteorological factors, such as temperature, humidity, and atmospheric pressure, as well as their variation and covariation on the incidence of BP. In addition we have reviewed the literature on the effect of meteorological conditions on facial nerve function.

Materials and methods

The study was conducted in the prefecture of Ioannina. This part of Northwestern Greece has a population of about 160,000 people. The climate of the area is that of a transient zone (between Mediterranean and Continental). Temperature and relative humidity, during the study period, have ranged between -9°C and 41°C, and between 7% and 99% respectively.

One hundred and seventy-one cases of BP sequentially admitted to our Department over a period of five years (from January 1995 to December 1999) were studied (Figure 1). Subjects with a history of diabetes mellitus, renal, liver, endocrinologic, and neoplastic diseases as well as head injury, post-surgical pareses and ear infections have been excluded from the study. A positive pregnancy test was an additional exclusion criterion [19]. BP day of onset was precisely recorded according to patients' history. Physical examination, auditory tests, and electrophysiologic tests were performed in all patients. Underlying infection was ruled out on the basis of laboratory evaluation, including complete blood count, C-reactive protein, and serological testing for viral disease
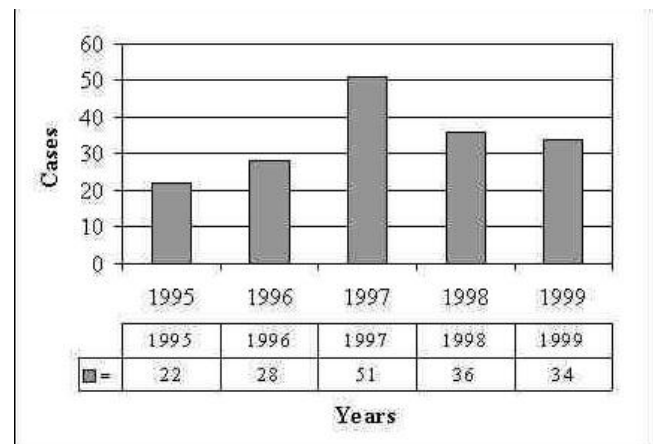

Figure 1
Yearly distribution of Bell's palsy cases.

(including hepatitis A, B, C, herpes simplex, HIV, Epstein-Barr, and cytomegalovirus).

The meteorological database included daily values of 13 parameters, recorded at the meteorological station of the University of Ioannina during the study period. The following parameters were recorded:

- Maximum Temperature (T_{max})

- Minimum Temperature (T_{min})

- Mean Temperature (T)

- Diurnal Temperature Range ($T_{range} = T_{max} - T_{min}$)

- Day to Day Change of Maximum Temperature (ΔT_{max})

- Day to Day Change of Minimum Temperature (ΔT_{min})

- Day to Day Change of Mean Temperature (ΔT)

- Mean Atmospheric Pressure reduced to sea level (P)

- Day to Day Change of Mean Atmospheric Pressure (ΔP)

- Mean Relative Humidity (RH)

- Day to Day Change of Mean Relative Humidity (ΔRH)

- Mean Water Vapor Pressure (e)

- Day to Day Change of Mean Water Vapor Pressure (Δe)
Water Vapor Pressure (e) was calculated by using Relative Humidity definition (1) and the Clausius- Clapeyron equation (2) as follows:

(1) $RH = e/e_s$

(2) $de_s/e_s = LdT/R_vT^2$

where e_s represents the saturated water vapor pressure, R_v the specific gas constant for water vapor and L represents the latent heat of vaporization. Water vapor pressure (e) is another humidity parameter, which is known to be directly related to the amount of water vapor in the atmosphere. A number of researchers used Relative Humidity to evaluate the influence of humidity on human health. However, this is not an appropriate approach, because Relative Humidity reflects the percentage of water saturation in the atmosphere and not the total amount of water vapor. In this respect, a specific amount of water vapor in the atmosphere corresponds to different Relative Humidity levels under different temperatures. Thus, Water Vapor Pressure has to be taken into account primarily.

The relationship between the number of cases of BP and the above meteorological parameters was assessed by using Pearson Chi-square (X^2) test, Factor Analysis (FA), and Cluster Analysis briefly described in the following paragraphs:

(a) The Pearson Chi-square (X^2) test is the most commonly used procedure for testing independence of row and column classifications in an unordered contingency table.

(b) Factor Analysis (FA) is used in order to reduce the dimensionality of a large data set of p correlated variables. Each of the p initial variables X_1, X_2, ..., X_p can be expressed as a linear function of m (m < p) uncorrelated factors, i.e. $X_i = a_{i1}F_1 + a_{i2}F_2 + ...a_{im}F_m$, where F_1, F_2, ..., F_m are the factors and a_{i1}, a_{i2}, ...a_{im} are the factor loadings. The values of each factor are called factor scores and they are usually presented standardized, having zero mean and unit variance [20,21]. The number m on the retained factors has to be decided, by using various rules [20–22] and considering the physical interpretation of the results [23].

(c) Cluster analysis (CA) is used in order to classify a series of n observations into different and characteristic homogenous groups (clusters). Each observation is defined by p variables and it corresponds to one point in the p-dimensional space. Each cluster consists of the points located 'close' to each other. The meaning of 'close' or 'far' between two observations i and j is defined by the square of the Euclidean distance

$$D_{i,j}^2 = \sum_{k=1}^{p} \left(x_{ik} - x_{jk} \right)^2$$

There are several clustering procedures. Here we used the k-means procedure which, at each step, groups observations into the cluster with the closer center and it recomputes the cluster centers. This process continues until no further changes occur in the centers [24].

In the first part of this work, the values of each meteorological parameter were classified in the 5 quintiles, in a way that the first quintile contains the lowest 20% and the fifth quintile the highest 20% of the values. For each quintile, the number of days with 0 and 1 events of BP were calculated and a contingency table was constructed for each meteorological parameter. There were no days with more than one BP events. The contingency table for maximum temperature is presented as an example. (Table 1)

Table 1: Contingency table for Maximum Temperature (T_{max})

Quintiles of T_{max}	Days	
	0 Events	**1 Event**
1 (T_{max} < 10.8°C)	331	34
2 (10.8°C < T_{max} < 15.4°C)	330	35
3 (15.4°C < T_{max} < 22.2°C)	328	37
4 (22.2°C < T_{max} < 28.8°C)	329	36
5 (T_{max} > 28.8°C)	336	29

For each of the 13 contingency tables Pearson Chi-square (X^2) test was applied, testing the null hypothesis of independence between the meteorological parameters quintiles and Bell's palsy events. The reason for using contingency tables instead of Pearson correlation is the large divergence of the medical data set from the Gaussian (normal) distribution (many days with zero events).

In the second part of this work, Factor Analysis and Cluster Analysis were used in order to obtain results of the dependence of BP events not on individual meteorological parameters but on the weather in general. At first, FA was applied on the 13 meteorological parameters and led to their reduction to 5 factors, which explain 85% of Ioannina weather variability. Detailed results of FA are not shown since data reduction is not the main purpose of this work but it is used as an intermediate stage. This re-
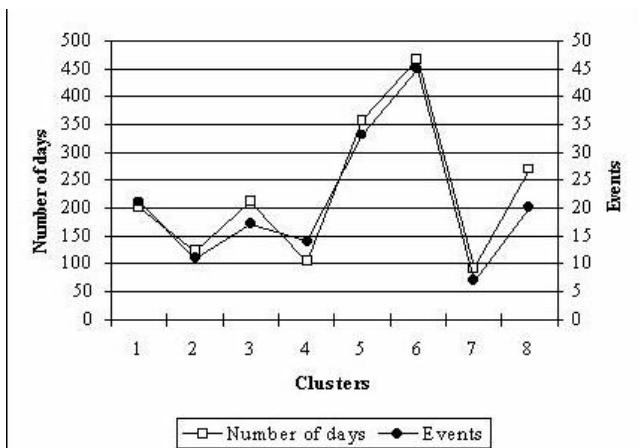
Figure 2
Correlation of variation of number of days and BP events with weather types (clusters).

duction to the main weather components, prior to the application of Cluster Analysis, is considered necessary for higher quality results by many researchers [25,26]. Then, Cluster Analysis was applied on the 1826 factor score cases (days) in order to group them objectively into groups of days presenting a characteristic weather type. The dependence of BP events on weather as a whole, was finally tested by applying Chi-square (X^2) test on a new Contingency table constructed by the Clusters found and the events of BP (0 and 1).

Results
In the first part of the study, we investigated the relationship between meteorological variables and the incidence of BP. The Chi-square (X^2) test was applied to the 13 contingency tables. There was no statistically significant correlation (Confidence Interval 95%) between BP events and each of the recorded meteorological parameters.

In the second part of the study, we searched for a relationship between weather types and the incidence of BP. The results of the application of Cluster Analysis on the factor scores time series revealed eight clusters (weather types) for the Ioannina prefecture (Table 2). The mean value of each meteorological parameter recorded from all days of each cluster was calculated so as to provide a realistic overall estimate of the corresponding weather type (Table 3). The frequency of Bell's palsy cases was not found significantly correlated to a specific weather type, at 95% Confidence level (Figure 2).

In order to obtain a quantitative statistical proof regarding the influence of weather on BP, Chi-square (X^2) test was applied on a contingency table consisting of the days of Bell's palsy events for each cluster (Table 4). The Chi-square (X^2) test did not reject the null hypothesis of independence at 95% confidence level, suggesting that there is not a statistically significant influence of weather on the frequency of BP.

Discussion
It was as early as the fifth century B.C. when Hippocrates suggested that weather changes might affect physical health [27,28]. A relationship between climatic characteristics, such as rain or wind, and chronic disease has been extensively investigated. This association has been demonstrated in patients suffering from rheumatoid arthritis [29], acute gouty arthritis [30], and SLE, and Behcet's disease [31].

The effect of cold on facial nerve function has been investigated. However, the influence of other atmospheric conditions, such as barometric pressure, humidity or even the covariation of such factors has not been adequately studied. Ding et al conducted an experimental study considering the biologic effects of freezing on the various tissues of the maxillofacial region, including skin, blood vessels, nerves, cartilage and bone. According to their results, a significant immediate paralysis of the facial nerve was evident, which recovered some weeks later [15]. Furthermore, the freezing effect of ice on the facial nerve function was investigated in an attempt to disclose the role of low temperature-induced vasoconstriction of the vasa nervorum in the pathogenesis of BP. In summary, there was not any significant effect on the nerve vessels physiological vasomotor regulation [16]. Hosomi studied the histological alterations following freezing the tympanic part of the facial nerve in mongolian gerbils. Remarkably, 95 % of the specimens exhibited facial palsy. Histological signs of nerve regeneration were obvious at 36 hours and facial nerve function normalized by the 35th day after freezing [17]. By contrast, Zealear et al (1995) did not show any significant effect on facial nerve function following acute and chronic exposure of the tympanic membrane to cold air, in cats and dogs [18].

In a search for the elusive cause of BP, several investigators have endeavored to analyze the influence of weather conditions on the incidence of the disease [4–14]. Most commonly, the possible role of temperature alone in the incidence of the disease attracted interest. In this respect, years were subdivided either as a "four season" pattern or as "warm and cold" periods. This approach is considered highly arbitrary since "seasons" may differ vastly with regard to temperature conditions in subsequent years at the very same location or at different locations. Mair and de Graaf, in 1974, reported the incidence and the epidemiology of BP in sub-arctic Norway during a five-year period. According to their conclusions, there

Table 2: The main characteristics of the weather type clusters defined for Ioannina prefecture (1995–99).

	Weather type	
Cluster 1	Humidity (relative and absolute) decrease	Mostly during the cold period of the year
Cluster 2	Temperature decrease	
Cluster 3	Absolute humidity and minimum temperature decrease	
Cluster 4	Domination of a low pressure system	
Cluster 5	Domination of a high pressure system	
Cluster 6	Persistence of warm and dry weather	Mostly during the warm period of the year
Cluster 7	High temperature, humidity (relative and absolute) increase	
Cluster 8	Humidity (relative and absolute) decrease	

Table 3: Mean value of each meteorological parameter in relation to the weather type clusters

Meteorological Parameter	Weather types (Clusters)							
	1	2	3	4	5	6	7	8
T_{max} (°C)	13.6	11.9	13.1	12.7	14.3	28.7	26.2	26.6
T_{min} (°C)	4.1	4.7	6.2	6.2	-0.3	11.6	15.3	13.1
T (°C)	8.8	8.3	9.7	9.5	7.0	20.2	20.8	19.9
T_{range} (°C)	9.5	7.2	6.9	6.6	14.5	17.2	11.1	13.5
ΔT_{max} (°C)	1.1	-4.1	0.0	-0.2	0.6	1.2	-2.7	-0.9
ΔT_{min} (°C)	0.0	-2.1	2.8	2.8	-1.5	-0.1	1.7	-0.7
ΔT (°C)	0.5	-3.3	1.5	1.4	-0.4	0.6	-0.4	-0.9
P (hPa)	1012.2	1010.8	1015.8	1007.3	1019.1	1014.9	1013.3	1014.0
ΔP (hPa)	0.1	-0.4	2.0	-6.2	0.7	-0.2	-0.1	0.5
RH (%)	61	78	75	80	69	55	73	62
ΔRH (%)	-12	6	0	3	4	-1	13	-3
e (hPa)	7.2	8.9	9.5	9.7	7.2	13.3	18.5	14.5
Δe (hPa)	-1.1	-1.4	1.0	1.1	0.2	0.4	2.8	-1.6

was not any significant difference in the incidence of the disease in Norway, in comparison to that of more temperate regions of the world [32]. Devriese (1977) investigated the relationship between atmospheric pressure and facial nerve palsy in a three-year study period. His statistical analysis, based on recordings of short time pressure changes, changes in two days, and the stability of atmospheric pressure changes within two days, failed to show a positive association between atmospheric pressure changes and the occurrence of BP [3]. In search for a relationship between weather conditions and facial nerve palsy, Herbert et al demonstrated a significant increment in the incidence of the disease on days with low barometric pressure, especially when a low barometric pressure period follows a high one, thus creating great pressure differences [33].

Although the number of the patients was not big enough to extract positive statistical conclusions on the epidemicity and seasonal distribution of Bell's palsy, no such indication was evident. According to the latest literature [8,14], the causative factor of Bell's palsy is the reactivation of Herpes Simplex Virus (HSV) in the ganglion cells. It is proposed to be a reactivation of latent infection and not an acquired one, therefore an epidemic distribution of the disease cannot be expected.

Conclusions
In the present study, we emphasized on the possible role of weather as the triggering factor of BP. In this respect, we studied a great number of atmospheric parameters using an entirely new statistical methodology. Moreover, we focused on the possible effect that changes of these

Table 4: Distribution of days with and without Bell's palsy events for each weather type cluster

Weather type (Cluster)	Days		Frequency (%) of BP events
	0 (No BP case)	**1** (One BP case)	
1	178	21	10.6%
2	112	11	8.9%
3	192	20	9.4%
4	90	14	13.5%
5	325	33	9.2%
6	423	45	9.6%
7	85	7	7.6%
8	249	20	7.4%

parameters might have on the incidence of BP over a five-year period.

According to our results, there was no statistically significant correlation between meteorological conditions and the actual incidence of BP. This could be due to the small number of registered cases in our area during the five-year study period. Furthermore, an inability to accurately record the day of onset of the disease, based on history taking only, may also provide a limitation. Patients' predisposition about their physical health changes as well as reluctance in seeking medical help for "minor symptoms" could also have an impact.

Future studies involving multicenter reports could be more successful in investigating the influence of environmental factors on facial nerve function. HSV reactivation in association with climatic differences between countries, as well as atmospheric pollution should be also taken into account.

Competing interests
None declared

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