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Research article

Weather conditions and sudden sensorineural hearing loss

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Abstract

Background: Climatic or meteorological condition changes have been implicated in the pathogenesis of Idiopathic Sudden Sensorineural Hearing Loss (ISSHL). We investigated the seasonal distribution of ISSHL and evaluated the influence of meteorological parameters (such as temperature, humidity, and atmospheric pressure), their variation and covariation on the incidence of the disease.

Methods: A total of 82 cases of ISSHL, admitted to our department over a five-year period, were enrolled in the study. Seasonal distribution of the disease was investigated by dividing the year in four seasons. Meteorological data 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 ISSHL was investigated by applying (χ^2) test on data from 13 contingency tables as well as by using logistic regression and t-test approaches. In addition, the influence of different weather types on the incidence of ISSHL was investigated using Cluster Analysis in order to create eight clusters (weather types) characteristic for the prefecture of Ioannina.

Results: The results of the study could not indicate any seasonal distribution of the disease. The incidence of ISSHL could not be significantly correlated either to any distinct meteorological parameter or to any specific weather type.

Conclusions: Meteorological conditions, such as those dominating in the Northwestern Greece, and/or their changes, have no proven effect on the incidence of ISSHL.

Background

There are few reports of Idiopathic Sudden Sensorineural Hearing Loss (ISSHL) in association with weather conditions; thus the relationship between them has not been completely detected yet. The consideration of weather as a possible triggering factor of ISSHL has been either approved [1,2] or rejected [3,4] by several authors. In this respect, general characteristics of the weather, such as atmospheric pressure and temperature, their variation and covariation have been mainly studied [1–4]. In order

Table 1: Contingency table of mean atmospheric pressure at sea level (P)

Quintiles of P	Days	
	0 Events	**1 Event**
1 (P < 1010.7 hPa)	347	18
2 (1010.7 hPa ≤ P < 1013.5 hPa)	351	14
3 (1013.5 hPa ≤ P < 1015.8 hPa)	348	17
4 (1015.8 hPa ≤ P < 1018.8 hPa)	351	14
5 (P ≥ 1018.8 hPa)	346	19

to investigate the possible effect of atmospheric conditions on ISSHL, we performed a detailed analysis, which included a large number of meteorological parameters as well as their combinations that produce various types of weather.

Materials and methods

The study was conducted over a period of five years (January 1995 to December 1999) in the prefecture of Ioannina, a part of Northwestern Greece with a population of about 160,000 people. The climatic conditions of the area are those of a transient zone (between Mediterranean and Continental), with mean monthly temperature ranging from 5°C (January) to 25°C (July) and mean monthly relative humidity fluctuating between 52% (July) and 82% (December). Temperature and relative humidity during the study period ranged between -9°C and 41°C, and between 7% and 99% respectively.

Eighty-two cases of ISSHL, sequentially admitted to our Department during the study period, were included in the study. Diagnosis of ISSHL was made after exclusion of the various possible causes of sudden hearing loss. Therefore, patients with a history of acute or chronic otitis media, mastoiditis, viral infections, syphilis, diabetes mellitus, hyperlipoproteinemia, use of ototoxic medication (salicylates, aminoglycoside antibiotics, diuretics etc), autoimmune diseases (SLE, Cogan's disease), head trauma, barotrauma, ear surgery, and head and neck neoplasms were excluded from the study. A positive pregnancy test was an additional exclusion criterion [5]. Date of onset of hearing loss was precisely recorded according to patients' history. Detailed otorhinolaryngological examination, with specific attention on audiometry (tune fork tests, pure tone audiometry, speech discrimination tests, tympanometry and acoustic reflex) and vestibular function testing, as well as neurological evaluation were performed in all patients. Laboratory evaluation included hematological examinations (complete blood count, C-reactive protein, erythrocyte sedimentation rate), coagulation studies, and serological chemical testing as well as tests for viral disease (including Hepatitis A, B, C, Herpes Simplex, HIV, Epstein-Barr, and Cytomegalovirus) and syphilis.

The first part of this study included investigation of the possible relationship between age (divided in age decades), and sex of the patients and the incidence of the disease. Study of seasonal distribution of ISSHL was performed by dividing each year in four conventional seasons: spring (1 March-31 May), summer (1 June-31 August), autumn (1 September-30 November), and winter (1 December- 28/29 February).

In the second part of the study, we examined the possible effect of each meteorological parameter on the incidence of ISSHL. The meteorological database included daily values of 13 parameters recorded at the meteorological station of the University of Ioannina during the study period. The parameters recorded were:

- 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 ($\Delta T_{>max}$)

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

- Day-to-Day Change of Mean Temperature (ΔT)

- Mean Atmospheric Pressure at 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 Clausius- Clapeyron formula (2) as follows:

(1) $RH = e / e_s$

(2) $de_s / e_s = LdT / R_v T^2$

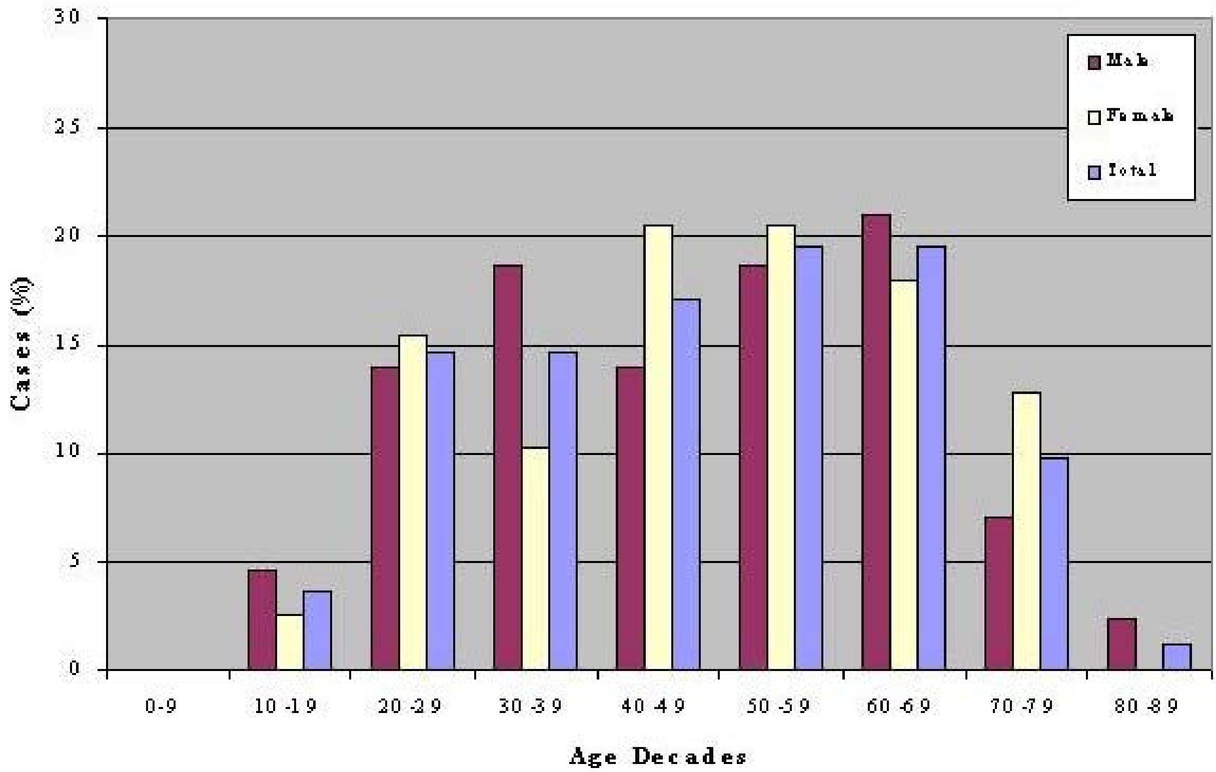

Figure 1
Distribution (%) of ISSHL events per age decade for men, women as well as for all the patients.

e_s represents the saturated water vapor pressure, R_v the specific gas constant for water vapor, and L the latent heat of vaporization. Water vapor pressure (e) is a humidity parameter directly related to the amount of water vapor contained in the atmosphere. Therefore, it should primarily be used in biometeorological studies instead of relative humidity [6]. The relationship between the number of cases of ISSHL and the above mentioned meteorological parameters was assessed by using Pearson Chi-square (χ^2) test, Logistic Regression, t-test, Factor Analysis (FA), and Cluster Analysis (CA) [6–10]. Pearson and Spearman correlations could not be applied because of the large divergence of the medical data set from the Gaussian (normal) distribution and the large number of days with zero events.

The values of each meteorological parameter were classified into 5 quintiles, in a way that the first quintile contained the lowest 20% and the fifth quintile the highest 20% of the values. The number of days with 0 and 1 event of ISSHL was calculated for each quintile and a contingency table was constructed for each meteorological parameter. There were no days with more than one ISSHL events. The contingency tables of mean atmospheric pressure at sea level (P) and day-to-day change of mean atmospheric pressure (ΔP) are presented as an example (Tables 1,2). Pearson Chi-square (χ^2) test was applied for each of the 13 contingency tables, testing the null hypothesis of independence between the meteorological parameter quintiles and the number of ISSHL events. Furthermore, Logistic Regression models, which take advantage of the detailed information of the data set, were applied. Alternatively, classical independent samples t-tests were also used, comparing the mean value of each meteorological parameter in days with and without ISSHL event.

In the third part of the study, FA and CA were used in order to assess the dependence of ISSHL events on the weather in general and not only on distinct meteorological parameters. At first, FA was applied to the 13 meteorological parameters leading to their reduction to 5 factors, which explain 85% of the weather variability in Ioannina. The results of FA are not presented, since data reduction represents an intermediate step of our analysis and not the aim of this work. This reduction to the main weather components, prior to the application of CA, has been consid-

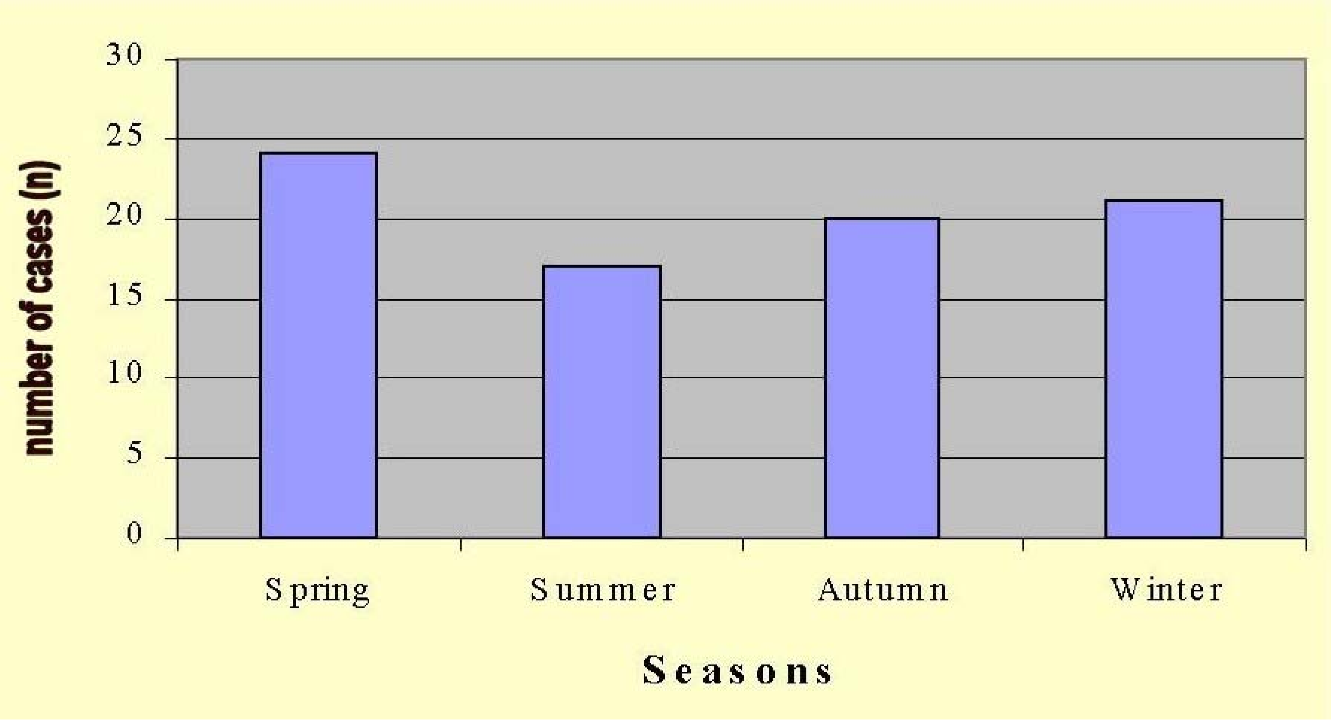

Figure 2
Intra-annual distribution of ISSHL events (seasonal values).

ered necessary by many researchers for obtaining high quality results [11,12]. Then, CA was applied to the 1,826 factor score cases (days) in order to group them objectively into groups of days presenting a characteristic type of weather. The dependence of ISSHL events on weather as a whole was finally tested by applying Chi- square (χ^2) test to a new contingency table, constructed by the clusters (weather types) found and the number of ISSHL events (0 and 1).

Results

The study included 82 patients suffering from ISSHL, with a mean age of 50.4 years (range 7–84 years). Forty-three patients were male (52.4%) and 39 female (47.6%). No statistically significant difference was found between mean male and mean female age (49.7 and 51.1 years respectively).

Distribution of the ISSHL events per age decade for men, women as well as for the total group of patients revealed an increment in the incidence of the disease starting from the third decade. Peak morbidity was found in the sixth and seventh decade of life (Figure 1).

The annual incidence of ISSHL in our prefecture was 10.25 cases per 100,000 population during the five years, while investigation of the inter-annual distribution (1995: 15 cases, 1996: 17, 1997: 14, 1998: 16, 1999: 20) did not reveal any statistically significant trend (test Mann-Kendall, Confidence Level 95%). The seasonal distribution of ISSHL (Figure 2) was also examined. The 5-year mean number of cases per season were evaluated and no significant differences were found among the four seasons at 95% confidence level (t-test, Analysis of Variance, Tukey's honestly significant difference test).

Table 2: Contingency table of day-to-day change of mean atmospheric pressure (ΔP)

Quintiles of ΔP	Days	
	0 Events	1 Event
1 ($\Delta P < -2.5$ hPa)	349	16
2 (-2.5 hPa $\leq \Delta P < -0.7$ hPa)	346	19
3 (-0.7 hPa $\leq \Delta P < 0.7$ hPa)	351	14
4 (0.7 hPa $\leq \Delta P < 2.5$ hPa)	352	13
5 ($\Delta P \geq 2.5$ hPa)	345	20

Table 3: Mean value of each meteorological parameter in relation to the weather types (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

Table 4: The main characteristics of the weather types (clusters) defined for Ioannina prefecture (1995–99)

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

In the second part of the study, Chi-square (χ^2) test, which was applied to the 13 contingency tables, revealed no statistically significant correlation (Confidence Level 95%) between ISSHL events and each of the recorded meteorological parameters. The Logistic Regression approach indicated no statistically significant logistic coefficients (at 95% confidence level) except for ΔT_{min} (p = 0.03), leading to the model: ln [odds(event)] = ln [Prob(event) / Prob(no event)] = -3.079 + 0.048 ΔT_{min}. Under this model, the effect of ΔT_{min} on ISSHL events appeared significant. Nevertheless, the odds ratio for the event being exp(0.048) = 1.05 [95% confidence interval (1.01, 1.10)] indicated that this effect was weak. Furthermore, the t-test approach revealed that the mean value of each of the 13 meteorological parameters in days with event did not differ significantly as compared to the days without event (95% confidence level). It is of interest that the mean value of ΔT_{min} in days with and without ISSHL event was -0.06°C and 1.23°C respectively, whereas the p-value for this test was 0.26 (not homogeneous variances).

In the third part of the study, CA application to the factor scores time series (days) revealed eight clusters (i.e. weather types) for the Ioannina prefecture. The mean value of each meteorological parameter for all days of each cluster was calculated (Table 3) and a realistic overall "picture" of the corresponding weather type was defined (Table 4). The frequency of ISSHL events appeared not to depend on

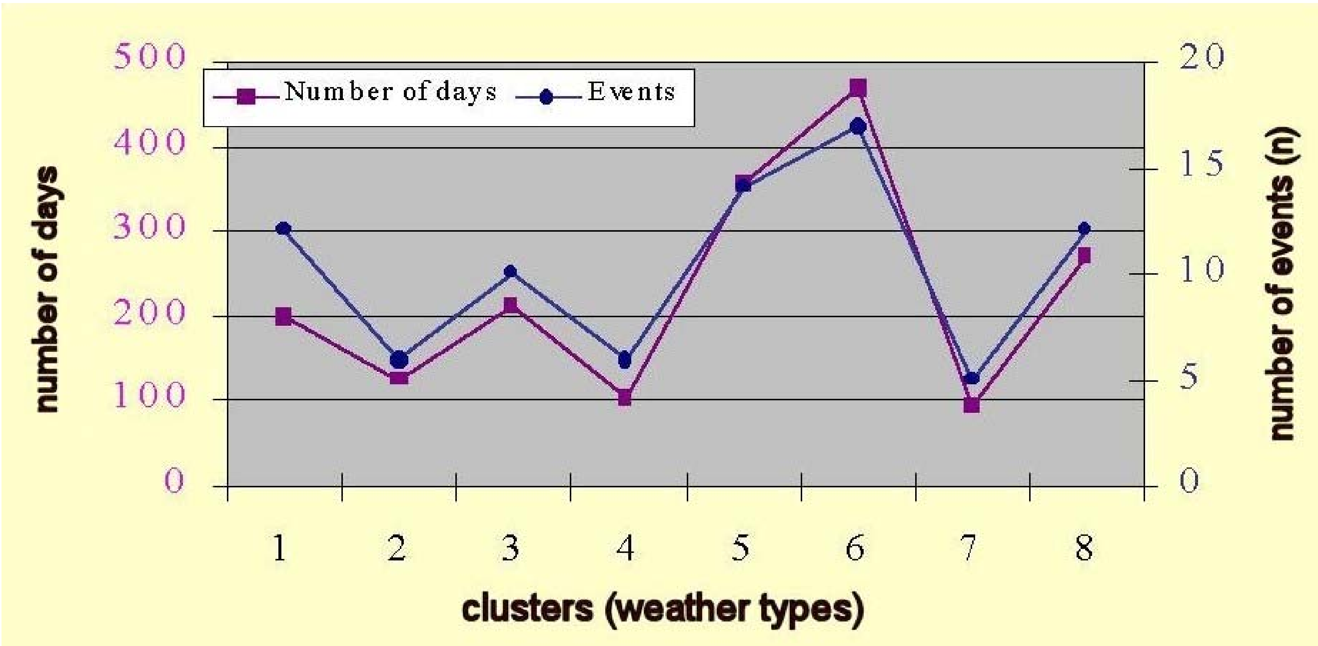

Figure 3
Number of days belonging to each of the 8 clusters and number of ISSHL events per cluster. The 8 clusters represent weather types characteristic of the study area.

weather, as the number of events per cluster covaried with the number of days per cluster (Figure 3). Chi-square (χ^2) test, which was applied on a contingency table consisting of the number of days with 0 and 1 event for each cluster (weather type), did not reject the null hypothesis of independence at 95% confidence level, suggesting that there is no statistically significant influence of weather on the frequency of ISSHL (Table 5).

Discussion

Sudden sensorineural hearing loss (SSHL) is a common otolaryngologic entity, causing considerable anxiety to the patient as well as the doctor. Different theories have evolved in an attempt to explain the pathogenesis of this disorder; inflammatory, vascular, traumatic, metabolic, neoplastic, and ototoxic [13,14]. Thus, the diagnosis of idiopathic SSHL is most commonly made after excluding all other pathologic entities possibly causing SSHL. The overall incidence of ISSHL has been reported to vary between 5 and 20 cases per 100,000 population annually, with an equal sex distribution and peak morbidity in the fourth or fifth decade of life [14].

In the fifth century B.C., Hippocrates suggested that weather changes might play a role in the deterioration of physical health [15]. Climatic characteristics, such as rain or wind, have since been repeatedly implicated in the pathogenesis of chronic disease. Such an association has been demonstrated in patients suffering from acute gouty arthritis [16], rheumatoid arthritis [17], SLE, and Behcet's disease [18]. The effect of weather conditions on Bell's palsy has also been investigated [19]. Nevertheless, the influence of specific meteorological conditions, such as barometric pressure, temperature and humidity, and their covariation on the incidence of ISSHL has been rarely discussed. Mees et al. reported that weather conditions are significantly correlated to the incidence of acute idiopathic hearing loss [1]. Accordingly, Herbert et al. found that the incidence of sudden hearing loss (along with Meniere's disease and Bell's palsy) is significantly affected by atmospheric pressure [2]. Their results indicated an increase in the incidence of sudden deafness in cases of major atmospheric pressure differences. In contradiction, Preyer could not establish a statistically significant correlation between the incidence of the disease and the absolute values or relative alterations of atmospheric pressure and temperature [3]. Mizukoshi et al. investigated the influence of a cold front, defined by specific meteorological conditions, on the incidence of sudden deafness [4]. Their results did not indicate a correlation between the onset of the disease and the passing of a cold front.

In the present study, in order to search for an association between weather conditions and ISSHL, we performed a detailed analysis based on an advanced methodology. The study included a variety of meteorological parameters,

Table 5: Distribution of days with and without ISSHL events for each weather type (cluster)

Weather type (Cluster)	Days		Frequency (%) of ISSHL events
	0 (No ISSHL case)	1 (One ISSHL case)	
1	187	12	6.0 %
2	117	6	4.9 %
3	202	10	4.7 %
4	98	6	5.8 %
5	344	14	3.9 %
6	451	17	3.6 %
7	87	5	5.4 %
8	257	12	4.5 %

their variation and covariation as well as 8 types of weather characteristic of our prefecture. The investigation of the dependence of ISSHL on 13 distinct meteorological parameters as well as on the weather in general differentiates our study from previous reports.

Our study results revealed an annual incidence of 10.25 cases per 100,000 population, which is similar to the previously reported for ISSHL. Although the incidence of the disease has been reported to increase among patients over 40 years of age, we found a significant increment over 20 years of age, with no differentiation between sexes. Investigation of the relationship between the four seasons of the year and the incidence of ISSHL failed to reveal a definite seasonal distribution of the disease. Furthermore, detailed statistical analysis of the covariation between multiple meteorological parameters and the incidence of ISSHL failed to prove a definite relationship between any distinct parameter or any specific weather type and the incidence of ISSHL.

Conclusions

Despite the relatively small number of patients, we investigated the influence of meteorological conditions on the incidence of ISSHL, applying an entirely new and detailed statistical methodology. The results of the study could not prove a statistically significant effect of weather conditions on the frequency of ISSHL. We, therefore, cannot support a possible role of the weather as a triggering factor in the pathogenesis of ISSHL.

Competing interests

None declared

Authors' Contributions

Author 1, V. D., conceived of the study, designed the study, and carried out the medical part of the study, the review of the literature as well as the writing of the manuscript. Author 2, C.-S. N., participated in the study design and carried out the medical part of the study, the review of the literature, and the writing of the manuscript. Author 3, A. B., participated in the study design, carried out the meteorological part along with the statistical analysis of the study and cooperated in the writing of the manuscript. Author 4, C. J. L., participated in the meteorological part and the statistical analysis of the study. Author 5, M. K., cooperated in the statistical analysis. Author 6, A. S., was the supervisor of the study.

All authors read and approved the final manuscript.

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