

Meteorological Conditions Related to the Onset of Idiopathic Sudden Sensorineural Hearing Loss

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Purpose: The objective of this study was to evaluate the effect of meteorological factors on the onset of idiopathic sudden sensorineural hearing loss (ISSHL). **Materials and Methods:** Meteorological data from 2005 to 2011 were obtained from the web-based “Monthly Weather Reports of the Meteorological Administration” database. Patients with ISSHL who visited our hospital during this same period and presented the precise day on which hearing loss developed were included in this retrospective study. Twelve meteorological factors were analyzed between the days when ISSHL onset was observed as well as the days when ISSHL did not occur. The weather conditions occurring 1–7 days before ISSHL onset were also analyzed to assess any possible delayed effects of meteorological factors on the onset of ISSHL. **Results:** During the study period, 607 patients were included for the study. Although mean and maximal wind velocities were higher for the days when ISSHL occurred than the days without ISSHL onset, after adjusting the value for multiple comparisons, we cannot find any significant relationship between any of meteorological factors and the onset of ISSHL. However, in analysis of time lag effect of the weather conditions, we found that there was still a significant difference in maximum wind speed on 5 days before ISSHL onset even after applying Bonferroni correction. **Conclusion:** The result of this study suggests that stronger wind speed may be related to the occurrence of ISSHL.

Key Words: Sudden hearing loss, meteorological factor, wind speed

INTRODUCTION

In the fifth century B.C., Hippocrates suggested that weather changes might play a role in the deterioration of physical health.¹ Climatic characteristics have since been repeatedly suggested for the pathogenesis of various diseases. Passage of weather fronts, sudden change of climate or wind direction, atmospheric pressure, and humidity can disturb the balance of the autonomic nervous and endocrine systems, thus suppressing the immune system. The association of weather conditions and the development of diseases have been demonstrated in gouty arthritis,² rheumatoid arthritis,³ systemic lupus erythematosus, Bechet's disease,⁴ pneumothorax,⁵ and various viral infections such as influenza,⁶ herpes zoster,⁷ respiratory syncytial virus,⁸ and varicella zoster virus.⁹

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Idiopathic sudden sensorineural hearing loss (ISSHL) is not a rare otologic disease, occurring in 5 to 20 per 100000 persons per a year.¹⁰ The etiologies of ISSHL are unclear, but considerable debate has included viral infection of the labyrinth, impairment of labyrinthine blood supply, autoimmune-mediated cochlear malfunction, and intracochlear membrane rupture.¹¹

There have been a number of studies that analyzed the effect of weather conditions on the development of ISSHL.¹²⁻¹⁷ Although several studies have reported a significant relationship between the onset of ISSHL and weather conditions,^{12,13} other studies have failed to show any correlation between weather and the development of ISSHL.¹⁴⁻¹⁷

Since viral neuropathology is considered to be one of the most important pathogenic mechanisms of ISSHL, and seasonal clustering of ISSHL onset has been frequently reported, we hypothesized that weather conditions may affect the onset of ISSHL. Thus, the authors aimed to evaluate the effect of these weather conditions such as atmospheric pressure, temperature, humidity, and wind speed on the onset of ISSHL. Additionally, we hypothesized that a time delay might exist following the weather condition before the development of ISSHL, and we aimed to evaluate the delayed effect of weather conditions for at least 7 days.

MATERIALS AND METHODS

Patients

The medical charts of patients who had been diagnosed with ISSHL at Incheon St. Mary's Hospital over a period of 7 years (from January 2005 to December 2011) were included in this study. Korean International Classification of Diseases code for "sudden idiopathic hearing loss" was used to search the hospital medical database. A retrospective chart review of the selected patients was conducted. Inclusion criteria were the patients who presented the exact day of onset, resided in Incheon city, and fulfilled the diagnostic criteria for ISSHL. The diagnostic criteria for ISSHL were hearing loss of at least 30 dB in three contiguous frequencies occurring within a 72-hour period without any specified causes. Patients with perilymphatic fistula, acoustic trauma, Meniere's disease, labyrinthitis, or acute low-tone hearing loss that fluctuated over several weeks or months were excluded. The study protocol was performed in accord with the principles of the Declaration of Helsinki and approved by the Institutional Review Board of The Catholic University of Korea.

Collection of meteorological data

The meteorological data for Incheon city during the same study period were available from the database at the Korean Meteorological Administration Website (http://www.kma.go.kr/weather/observation/data_monthly.jsp). Information was obtained from the database for the seven parameters examined in the analysis: mean atmospheric pressure, mean temperature (T), maximum temperature (T_{\max}), minimum temperature (T_{\min}), mean relative humidity, mean wind speed, and maximum wind speed. Day-to-day differences in the mean value of each parameter were calculated from the data. The daily temperature range was defined as the difference between T_{\max} and T_{\min} . All study participants were assumed to have experienced identical climatic conditions. The days on which ISSHL onset was reported over the whole 7 years of the study were defined as ISSHL (+) days, and the days on which ISSHL onset was not reported were defined as ISSHL (-) days. Each weather parameter was compared between the ISSHL (+) and ISSHL (-) days. The data for meteorological parameters recorded 1-7 days before the onset of ISSHL were also compared between the ISSHL (+) and ISSHL (-) days.

Statistical analysis

Data were analyzed using SPSS software version 18.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean±standard deviation. Each meteorological parameter was compared between the ISSHL (+) and ISSHL (-) days using a Mann-Whitney U test. For multiple comparisons, Bonferroni correction was used. The criterion for statistical significance was a *p*-value less than 0.05.

RESULTS

During the study period, 607 patients were enrolled in the study. There were 331 female and 276 male patients. The mean age of the patients was 51.5±14.9 years. ISSHL onset was recorded on 521 of the total 2556 days of the study, including 71 days during which there was the simultaneous onset of two cases of ISSHL, 6 days with the onset of three cases of ISSHL, and 1 day with the onset on four cases of ISSHL. In the statistical analysis, the days with two or more cases were weighted by the number of ISSHL cases reported on that day.

South Korea tends to have a humid continental climate and is affected by the East Asian monsoon, with heavier

precipitation in the summer during a short rainy season that extends from the end of June to the end of July. The mean yearly temperature ranges from -4.0°C in January to 23.9°C in August. The mean value of each meteorological parameter for the 7 years of the study is presented in Table 1. The mean temperature was $12.5\pm 9.7^{\circ}\text{C}$, the mean atmospheric pressure was 1016.0 ± 8.1 hPa, the mean relative humidity was $67.0\pm 15.1\%$, and the mean wind speed was 2.8 ± 1.3 m/s. During the study period, the temperature ranged between -15.0°C and 33.8°C and the relative humidity ranged from 26% to 99%.

When each meteorological parameter was compared between ISSHL (+) and ISSHL (-) days, statistical analysis

Table 1. Meteorological Parameters from 2005 to 2011

| Meteorological parameters | Mean \pm S.E. |
|---|------------------|
| Mean wind speed (m/s) | 2.8 \pm 1.3 |
| Maximum wind speed (m/s) | 5.6 \pm 2.1 |
| Mean atmospheric pressure (hPa) | 1016.0 \pm 8.1 |
| Day-to-day difference in atmospheric pressure (hPa) | 0.0 \pm 3.7 |
| Mean temperature ($^{\circ}\text{C}$) | 12.5 \pm 9.7 |
| Day-to-day difference in temperature ($^{\circ}\text{C}$) | 0.0 \pm 2.2 |
| Maximum temperature ($^{\circ}\text{C}$) | 16.4 \pm 9.8 |
| Minimum temperature ($^{\circ}\text{C}$) | 9.3 \pm 10.0 |
| Daily temperature range ($^{\circ}\text{C}$) | 7.1 \pm 2.7 |
| Mean relative humidity (%) | 67.0 \pm 15.1 |
| Day-to-day difference in humidity (%) | 0.0 \pm 13.3 |
| Minimum relative humidity (%) | 45.6 \pm 17.3 |

S.E., standard error.

using Mann-Whitney U test demonstrated that mean and maximal wind velocities were significantly higher for the days when ISSHL occurred than the days without ISSHL onset. These did not reach statistical significance until after Bonferroni correction had been applied. The other meteorological parameters of the days when ISSHL occurred were not significantly different from the days on which ISSHL onset was not observed (Table 2).

When considering time lag effects of weather conditions 1–7 days before ISSHL onset, it was revealed that the maximum wind speed on 5 days before ISSHL onset was significantly higher for ISSHL onset days than for days with no ISSHL onset ($p=0.036$; Mann-Whitney U test with Bonferroni correction) (Fig. 1). Mean values for the other meteorological parameters during days 1–7 before ISSHL onsets were not significantly different from the control time period.

DISCUSSION

Various diseases, such as infectious diseases, rheumatic diseases, and spontaneous pneumothorax, have been considered to be affected by weather conditions.²⁻⁹ The effects of weather conditions on the onset of ISSHL have been studied by several authors (Table 3).¹²⁻¹⁷ Two of those studies reported a positive relationship between weather conditions and onset of ISSHL,^{12,13} and suggested that low atmospheric pressure was correlated with high occurrence of ISSHL. However, consideration of weather as a possible triggering

Table 2. Comparison of the Meteorological Parameters on Days with and without ISSHL Onset

| Parameters | ISSHL (-) day | ISSHL (+) day | <i>p</i> value |
|---|------------------|------------------|----------------|
| Mean wind speed (m/s) | 2.8 \pm 1.3 | 2.9 \pm 1.4 | 0.03* |
| Maximum wind speed (m/s) | 5.6 \pm 2.1 | 5.8 \pm 2.2 | 0.03* |
| Mean atmospheric pressure (hPa) | 1016.0 \pm 8.1 | 1016.0 \pm 8.2 | 0.93 |
| Day-to-day difference in atmospheric pressure (hPa) | 0.0 \pm 3.8 | -0.2 \pm 3.8 | 0.59 |
| Mean temperature ($^{\circ}\text{C}$) | 12.5 \pm 9.8 | 12.5 \pm 9.5 | 0.79 |
| Day-to-day difference in temperature ($^{\circ}\text{C}$) | -0.0 \pm 2.3 | -0.1 \pm 2.2 | 0.75 |
| Maximum temperature ($^{\circ}\text{C}$) | 16.4 \pm 9.8 | 16.3 \pm 9.6 | 0.67 |
| Minimum temperature ($^{\circ}\text{C}$) | 9.2 \pm 10.1 | 9.2 \pm 9.7 | 0.88 |
| Daily temperature range ($^{\circ}\text{C}$) | 7.2 \pm 2.5 | 7.1 \pm 2.3 | 0.48 |
| Mean relative humidity (%) | 67.0 \pm 15.2 | 66.7 \pm 14.7 | 0.54 |
| Day-to-day difference in humidity (%) | -0.0 \pm 13.2 | 0.1 \pm 13.9 | 0.41 |
| Minimum relative humidity (%) | 45.7 \pm 17.4 | 45.2 \pm 16.6 | 0.64 |

ISSHL, idiopathic sudden sensorineural hearing loss.

The results presented are means \pm standard errors. ISSHL (-) day: days when no ISSHL onset was reported; ISSHL (+) day: days when ISSHL onset was reported.

**p*-value <0.05; Mann-Whitney U test.

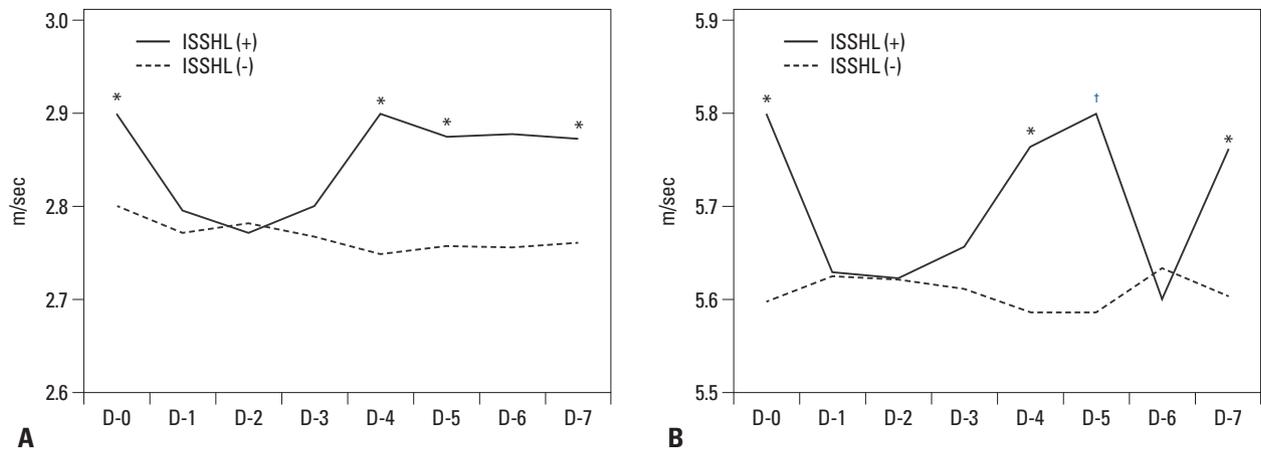


Fig. 1. Serial distributions of mean wind speed (A) and maximal wind speed (B) on days 0–7 before ISSHL onset. Mean and maximal wind speeds on days 0, -4, -5, and -7 (D₀, D₋₄, D₋₅, and D₋₇) were significantly higher for ISSHL onset days than for days with no ISSHL onset. ISSHL (-): days when no ISSHL onset was reported; ISSHL (+): days when ISSHL onset was reported. *Statistically significant using Mann-Whitney U test. †Statistically significant using Mann-Whitney U test with Bonferroni correction. ISSHL, idiopathic sudden sensorineural hearing loss.

Table 3. Results of Studies Reporting the Influence of Weather Condition on the Occurrence of ISSHL

| Authors | Study period (yrs) | No. of patients | Association of weather and ISSHL | Yr | Country |
|----------------------------------|--------------------|-----------------|----------------------------------|------|---------|
| Mees, et al. ¹² | 1 | >500 | S (atmospherics) | 1987 | Germany |
| Herbert, et al. ¹³ | 1 | 32 | S (atmospheric pressure) | 1987 | Germany |
| Mizukoshi, et al. ¹⁴ | 6 | 70 | NS | 1995 | Japan |
| Preyer ¹⁵ | 1 | 128 | NS | 1996 | Germany |
| Danielides, et al. ¹⁶ | 5 | 82 | NS | 2002 | Greece |
| Lin, et al. ¹⁷ | 5 | 8712 | NS | 2006 | Taiwan |

NS, not significant; S, significant; ISSHL, idiopathic sudden sensorineural hearing loss.

factor of ISSHL has also been rejected by four recent reports.¹⁴⁻¹⁷ Most recently, a study by Lin, et al.¹⁷ failed to show any relationship between the onset of ISSHL and weather conditions, when they studied monthly ambient temperature, relative humidity, atmospheric pressure, rainfall, hours of sunshine, and maximal and minimal temperatures. Their study was the largest study and included more than 8000 subjects. However, a weak point of their study was that no specific audiometric criteria of ISSHL were identified; rather, the report relied on hospitalizations with a diagnostic code of sudden hearing loss.¹⁷ We used a 7-year data set, which is the longest study period reported and has a large number of patients. Strict diagnostic criteria were also used to explore the association between meteorological factors and development of ISSHL. The results of our study suggested that wind speed may affect the development of ISSHL. To our knowledge, this is the first report on the relationship between wind speed and ISSHL.

The two predominant theories regarding the development of ISSHL are viral infection/reactivation and vascular compromise. Some suggest that neurotropic viruses, such as herpes simplex cytomegalovirus and rubella, may be the

cause of ISSHL by way of direct viral invasion to the cochlea or cochlear nerve, reactivation of a latent virus within the spiral ganglion, or immune-mediated mechanisms.^{11,18} It has also been reported that infection due to neurotropic virus such as herpes zoster⁷ and varicella zoster virus,⁹ as well as viral pathogens of acute respiratory tract infection, such as influenza A, RSV, and adenovirus, were related to weather conditions including mean temperature, humidity, and wind velocity.¹⁹

Interruption of vascular flow to the cochlea is thought to be another major cause of ISSHL. Many authors have reported that there is a positive association between cardiovascular risk factors and ISSHL.^{20,21} Seasonal effects have been suggested as contributing factors of stroke with ischemic stroke being more strongly associated with seasonal factors than hemorrhagic stroke.²² The occurrence of acute myocardial infarction is associated with some meteorological factors such as low temperature and low atmospheric pressure.²³ Furthermore, viral- and vascular-induced cochlear ischemia could be a common pathway in the development of ISSHL since viral infection might cause vascular obstruction through the precipitation of hemagglutination, in-

flammatory capillary edema, or induction of a hypercoagulable state.¹¹

We assume that stronger wind may induce viral reactivation of a latent neurotropic virus within the spiral ganglion and increase the risk of microvascular ischemia. The mechanisms by which faster wind speed can increase the risk of viral reactivation and microvascular ischemia remain unknown. However, higher wind speed is reported to be associated with the development of idiopathic facial palsy²⁴ and vestibular neuritis,²⁵ and the etiology is considered to be similar to that of ISSHL, supporting the association of higher wind speed and the onset of ISSHL.

This study had some limitations due to its retrospective design. It was not possible for us to collect information such as a recent history of upper respiratory tract infection, lifestyle, and serologic studies regarding viral markers for subjects. Secondly, the day of onset was determined from the self-reported histories of the patients, which may include false information. More extensive studies with a prospective and multicenter design involving ISSHL cases in this district are necessary to clarify the influence of meteorological factors on the onset of ISSHL.

In conclusion, the results of this study suggest that faster wind speed is related to the occurrence of ISSHL in this district. We assume that stronger wind may induce viral reactivation of a latent neurotropic virus within the spiral ganglion and increase the risk of microvascular ischemia. A nation-wide prospective study would be necessary to better demonstrate a relationship between the development of ISSHL and meteorological factors.

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