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Effects of meteorological factor and air pollution on sudden sensorineural hearing loss using the health claims data in Busan, Republic of Korea

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ABSTRACT

Purpose: Specific meteorological factors, including air pollution in the form of particulate matter (PM), affect the development of otologic disease and have adverse effects on the cardiovascular and respiratory systems. This study investigated relationships between the development of sudden sensorineural hearing loss(SSNHL) and meteorological factor with air pollution including PM.

Materials and methods: The daily patient number in 2015 admitted to the hospital with SSNHL were extracted from the Health Insurance Review and Assessment Service Bigdata in Busan. The meteorological factors and air pollution data of Busan area were obtained from meteorological stations in Busan. The relationship between the number of hospitalizations and the climatic factors was checked.

Results: SSNHL patient group showed more common in women, and the highest rates were observed in patients in their 50s. The daily mean patient numbers were 2.27. The number of SSNHL patients in spring was statistically significantly higher than that in summer. The mean daily PM10 and PM2.5 concentrations were 48.0 and 29.4 μg/m^3, respectively. The mean wind speed, maximum wind speed and daily atmospheric pressure range was weakly positively associated with SSNHL patient number. There were weak negative correlations between maximum PM2.5 and SSNHL admissions. The mean temperature and wind chill index showed non-significantly negative relationships with SSNHL admissions.

Conclusions: In Busan area, statistically significant weak relationships were detected between the daily numbers of patients admitted to the hospital with SSNHL and meteorological data, including PM level. Further investigation of these associations is required.

1. Introduction

Emergency otologic conditions such as sudden sensorineural hearing loss (SSNHL) require urgent evaluation, followed by appropriate treatment [1]. Viral infection, vascular occlusion, neoplasm, and immunologic factors have been suggested as potential causes of SSNHL, but the evidence to date remains unclear [2].

The global trend of urbanization and industrialization is increasing the problem of air pollution worldwide, and there is increasing concern about it. Recently, there have been many studies on the health effects of particulate matter (PM). PM is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air [3]. It is usually measured and managed in two ways, depending on whether the diameter of the particles is < 2.5 μm (PM2.5) or < 10.0 μm (PM10). Exposure to PM has been identified as a cause of various health problems including increased hospital admissions, emergency room visits, exacerbation of chronic respiratory and cardiovascular diseases, decreased lung function, and premature mortality [4].

Busan is the second largest city in South Korea. Located at the southeast end of the country, facing the sea and surrounded by mountains in the north, the climate is warm and humid. This metropolitan city has the largest port in South Korea and has a lot of automobile exhaust due to its large population. In addition, mid-level industry is relatively well developed in the region. Therefore, the PM

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level in Busan is relatively high.

Associations between meteorological factors and the onset of SSNHL have been investigated, but no studies have demonstrated significant relationships between them and air pollution parameters such as PM. In the current Busan-based study, we investigated whether the onset of SSNHL was associated with meteorological factors and air pollution including PM levels.

2. Materials and methods

Daily hospital admission numbers for SSNHL in Busan from January 2015 to December 2015 were retrospectively extracted using the Health Insurance Review and Assessment Service (HIRA) Bigdata database. In the Republic of Korea, the entire population, including resident aliens, is enrolled in the Korean National Health Insurance Service (NHIS), and HIRA is an organization that reviews and evaluates the appropriateness of the claimed NHIS medical activities. The Bigdata database managed by this organization includes patient demographics, medical service use, and medication information, among other things. Within this database, patients who were admitted to the hospital via an outpatient clinic or emergency room, with an International Classification of Diseases code of H91.2(SSNHL), were identified as patients with SSNHL patient. To rule out duplicate hospitalizations in the calculation of patient numbers, we counted only one case of re-admission with the same diagnosis within 2 weeks after discharge. This study was approved by the institutional review board of the Pusan National University Yangsan Hospital (PNUYH IRB, number 05-2016-175).

Meteorological factor data were measured by the Busan Regional Meteorological Administration located in Jung-gu, Busan, and obtained from the Korea Meteorological Administration website (www.kma.go.kr). The meteorological factors analyzed were mean temperature, daily temperature range, mean wind speed, maximum wind speed, mean sea level atmospheric pressure, daily sea level atmospheric pressure range, mean dew point and wind chill index. The wind chill index was calculated using the daily mean temperature and mean wind speed according to the formula suggested by the Joint Action Group for Temperature Indices (2001) as follows:

$$Twc = 13.12 + 0.6215Ta - 11.37V^{+0.16} + 0.3965TaV^{+0.16}$$

where Twc is the wind chill index(°C), Ta is the air temperature (°C), and V is the wind speed(km/h).

Air pollution parameters are mean sulfur dioxide(SO_2), mean carbon monoxide(CO), mean ozone(O_3), mean nitrogen dioxide(NO_2) and PM levels. Air pollution data were measured at the same location and recorded hourly based on the levels reported on the Korea Environment Corporation website (www.airkorea.or.kr). PM data consisted of daily mean PM2.5 and PM10 levels and daily maximum PM2.5 and PM10 levels.

Statistical analyses were performed using SAS software version 9.2 (SAS Institute, Cary, NC). The total number of health insurance beneficiaries in the HIRA database and the prevalence rates of SSNHL were determined. To analyze the seasonal trend of SSNHL, the average number of patients per season was compared by ANOVA analysis. The distribution of SSNHL patients was regarded as the Poisson distribution and the log linear model was used to estimate the seasonal odds ratio. To investigate the effects of meteorological factors including air pollution on SSNHL, mean daily temperature range, mean wind speed, maximum wind speed, mean atmospheric pressure, daily pressure range, mean dew point and wind chill index, mean SO_2, mean CO, Mean O_3, mean NO_2, daily mean PM2.5 and PM10, and daily maximum PM2.5 and PM10 were compared with the daily number of SSNHL patients admitted on the same day. Pearson's correlation coefficient analysis was used to analyze associations. In such analyses, the closer the R value is to 1 the stronger the correlation, and a negative value indicates a negative correlation. $p < 0.05$ was considered statistically significant.

Table 1
Summary of the sudden sensorineural hearing loss patient data.

Variables	Number
Number of patients (prevalence[a])	817 (23.4)
Male (prevalence[a])	350 (20.5)
Female (prevalence[a])	467 (26.5)
Mean age	51.0 ± 16.5
Mean number of patients daily	2.27 ± 2.0
Mean duration of admission	7.1 ± 2.7

[a] Per 100,000 population.

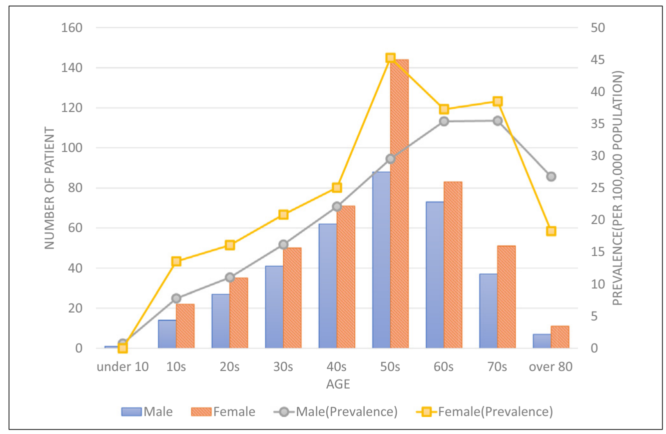

Fig. 1. Sex and age specific patient numbers and prevalence of sudden sensorineural hearing loss in 2015. In the sudden sensorineural hearing loss patient group, the highest numbers of patients were aged in their 50s, and prevalence increased with age.
SSNHL, sudden sensorineural hearing loss.

Table 2
Summary of meteorological factor and air pollution including particulate matter data derived from Busan, South Korea.

Variables	Mean ± SD	Maximum	Minimum
Meteorological data			
Mean temperature (°C)	15.48 ± 7.51	29.1	−2.2
Daily temperature range (°C)	7.33 ± 2.39	17.2	1.3
Mean wind speed (m/s)	3.10 ± 1.15	8.9	1.1
Maximum wind speed (m/s)	10.39 ± 3.26	25.3	4
Mean atmospheric pressure (hPa)	1015.93 ± 7.52	1034.4	995.4
Daily pressure range (hPa)	5.12 ± 2.95	21.3	1.3
Mean dew point (°C)	8.81 ± 10.23	24.9	−17.4
Wind chill index (°C)	15.08 ± 9.13	31.44	−7.36
Air pollution data			
Mean sulfur dioxide (ppm)	0.0085 ± 0.0046	0.0254	0.0011
Mean carbon monoxide (ppm)	0.431 ± 0.096	0.770	0.208
Mean ozone (ppm)	0.024 ± 0.009	0.060	0.004
Mean nitrogen dioxide (ppm)	0.027 ± 0.010	0.060	0.008
Mean PM10 (μg/m^3)	48.01 ± 24.10	240.50	12.96
Maximum PM10 (μg/m^3)	74.80 ± 35.79	352	21
Mean PM2.5 (μg/m^3)	29.40 ± 13.65	81.23	4.88
Maximum PM2.5 (μg/m^3)	46.59 ± 19.10	107	7

SD, standard deviation; ppm, parts per million; PM, particulate matter.

3. Results

The characteristics of patients with SSNHL are shown in Table 1. In the case of SSNHL, the total number of patients was 817 (mean age 51.0 ± 16.5 years), and prevalence was 23.4 per 100,000 population. The proportion of female patients was higher, the daily mean number of patients was 2.27 ± 2.0, and the mean hospital stay was 7.1 ± 2.7 days. Of the age-groups analyzed, the highest numbers of patients were in their 50s, but the prevalence increased with age

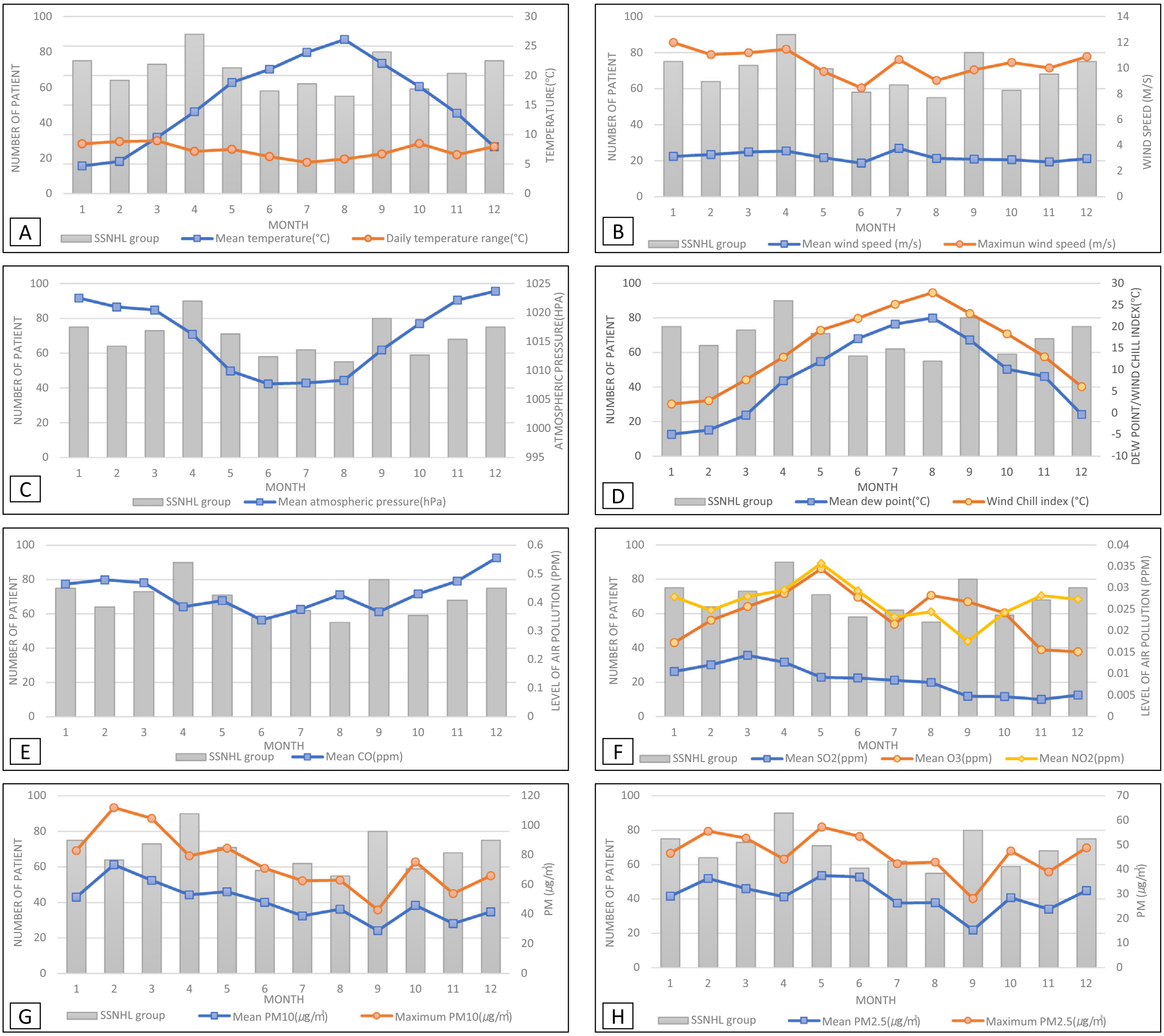

Fig. 2. Monthly distribution of sudden sensorineural hearing loss patients in conjunction with meteorological factor and air pollution including particulate matter levels. The SSNHL group had the largest number of patients in April and the smallest number in August. (A) The monthly distribution of mean temperature and daily temperature range showed seasonal variation. (B) Mean wind speed and maximum wind speed were higher in winter. (C) The monthly distribution of mean atmospheric pressure showed seasonal variation. (D) The monthly distribution of mean dew point and wind chill index showed similar trend with mean temperature (E, F) The level of air pollution showed seasonal variation. (G, H) Monthly mean and maximum PM10 and PM2.5 were higher in late winter and spring.
SSNHL, sudden sensorineural hearing loss; CO, carbon monoxide; SO2, sulfur dioxide; O3, ozone; NO2, nitrogen dioxide; PM, particulate matter.

Table 3
Seasonal trend of the sudden sensorineural hearing loss patients.

	Number of patient	Mean ± SD	Odds ratio (95% CI)	p Value
Spring	230	2.5 ± 0.2	1	–
Summer	172	1.9 ± 0.2	0.75 (0.61, 0.91)	**0.004**
Fall	204	2.2 ± 0.2	0.89 (0.73, 1.07)	0.212
Winter	211	2.3 ± 0.2	0.92 (0.76, 1.11)	0.366

SD, standard deviation; CI, confidence interval.
Bolded data means "statistically significant"

(Fig. 1).

Meteorological factors and air pollution including PM levels in 2015 are summarized in Table 2. Fig. 2 shows monthly data pertaining to the numbers of patients with SSNHL. The mean temperature, mean atmospheric pressure, mean dew point, and wind chill index showed a clear seasonal variation. Mean SO_2, Mean O_3, Mean NO_2, PM10 and PM2.5 showed a tendency to increase between February and June, and mean CO increased in winter season. With regard to SSNHL, the highest number of patients were admitted in April, and the lowest, in August. In the ANOVA analysis, there was no significant difference in the mean number of patients between the four seasons. The analysis of the odds ratio revealed that the number of patients decreased statistically significantly in the summer than in the spring (Table 3).

Statistical analyses were performed to assess correlations between changes in patient numbers and meteorological factors and air pollution including PM levels. In the SSNHL group, there were weak negative correlations between the mean numbers admitted to the hospital and both temperature and daily temperature range, but neither correlation was not statistically significant. The mean wind speed and maximum

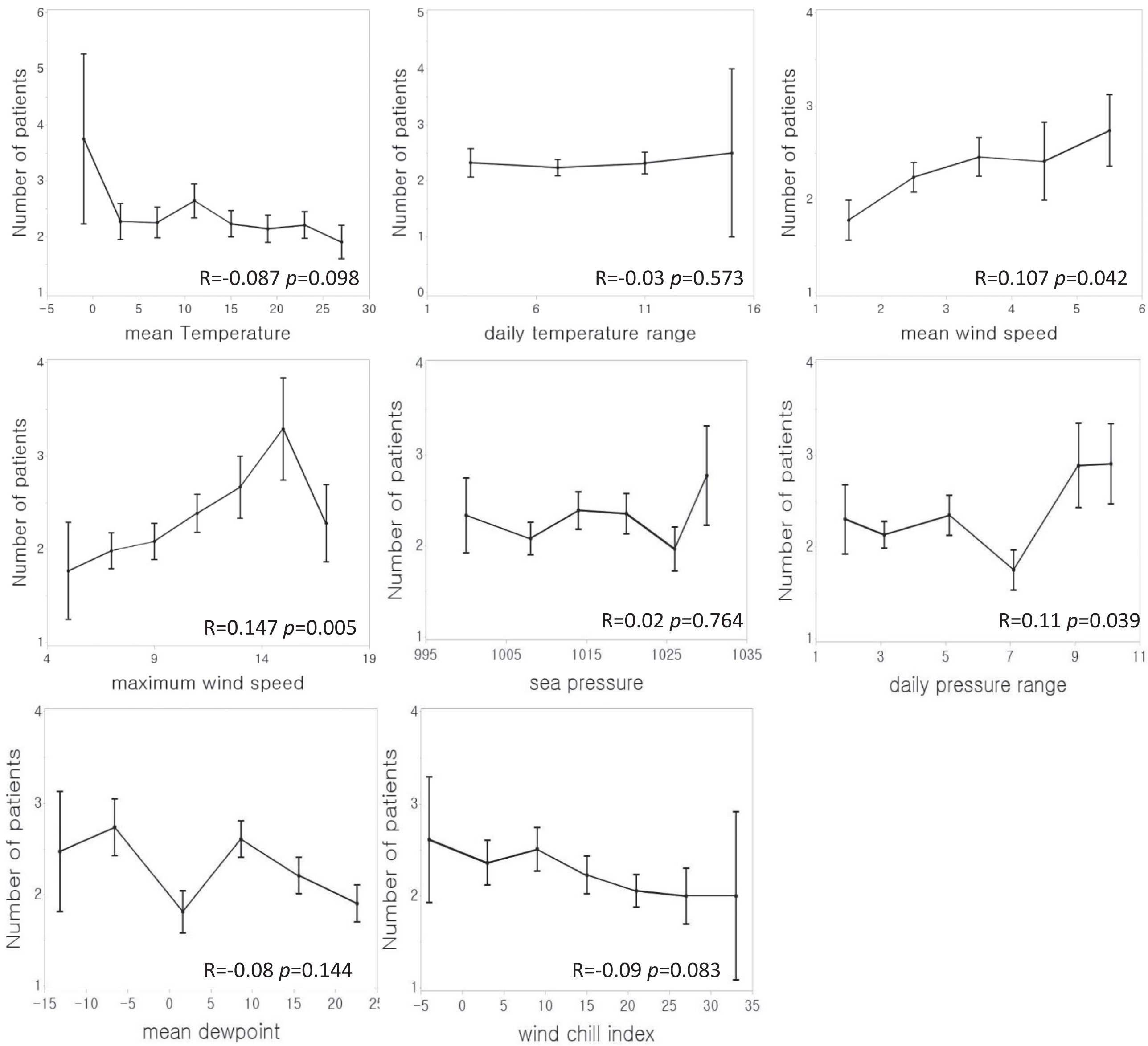

Fig. 3. Relationships between daily numbers of sudden sensorineural hearing loss patient admissions and meteorological factors. Mean wind speed (R = 0.107, p = 0.042) and maximum wind speed (R = 0.147, p = 0.005) exhibited a statistically significant weakly positive correlation with the number of admissions. Daily sea level atmospheric pressure range (R = 0.11, p = 0.039) showed a statistically significant weakly positive correlation with the number of admissions. SSNHL, sudden sensorineural hearing loss.

wind speed were weakly but statistically significantly positively correlated with the number of patients admitted. Mean sea level atmospheric pressure and wind chill index were not correlated with the number of patients. However, daily pressure range showed weakly positive correlation with number of SSNHL patient (Fig. 3).

Air pollution parameters including mean SO_2, mean CO, mean O_3, mean NO_2, mean PM10, maximum PM10 and mean PM2.5 showed no significant relationship with number of SSNHL patient. However, Maximum PM2.5 level was weakly but statistically significantly negatively correlated with the number of SSNHL patients admitted (Fig. 4).

4. Discussion

SSNHL is characterized by rapid onset, occurring over a 72-hour period, and a subjective sensation of hearing impairment in unilateral or bilateral ears. Audiologically, SSNHL is defined as a decrease in hearing of ≥30 decibels (dB), affecting at least 3 consecutive frequencies [1]. Various potential causes of SSNHL have been suggested, but to date no definitive cause has been identified. In studies investigating viral infection in this context, 65% of patients had a history of upper respiratory tract infections before the onset of SSNHL [5,6], and in one case series, mumps virus was associated with approximately 7% of all cases of SSNHL [7]. Measles and rubella have also been reported to be serologically associated with SSNHL [2,6,8]. Westmore et al. [9] detected live mumps virus in the perilymph of SSNHL patients after mumps parotitis. Notably, however, the prevalence of these infectious diseases have decreased in recent decades following widespread vaccination, but there has been no significant corresponding change in the number of SSNHL patients [10]. In addition, there is no test for confirming reactivation of the herpesviridae family (herpes simplex types 1 and 2, varicella-zoster virus, cytomegalovirus, Epstein-Barr virus, human herpes virus 6, 7, and 8) viruses.

The cochlea is an organ that is supplied with blood by an end artery. There have been many studies investigating whether a vascular problem is the cause of SSNHL. Various mechanisms, including atherosclerosis, hypotension, and vasospasm have been studied but no

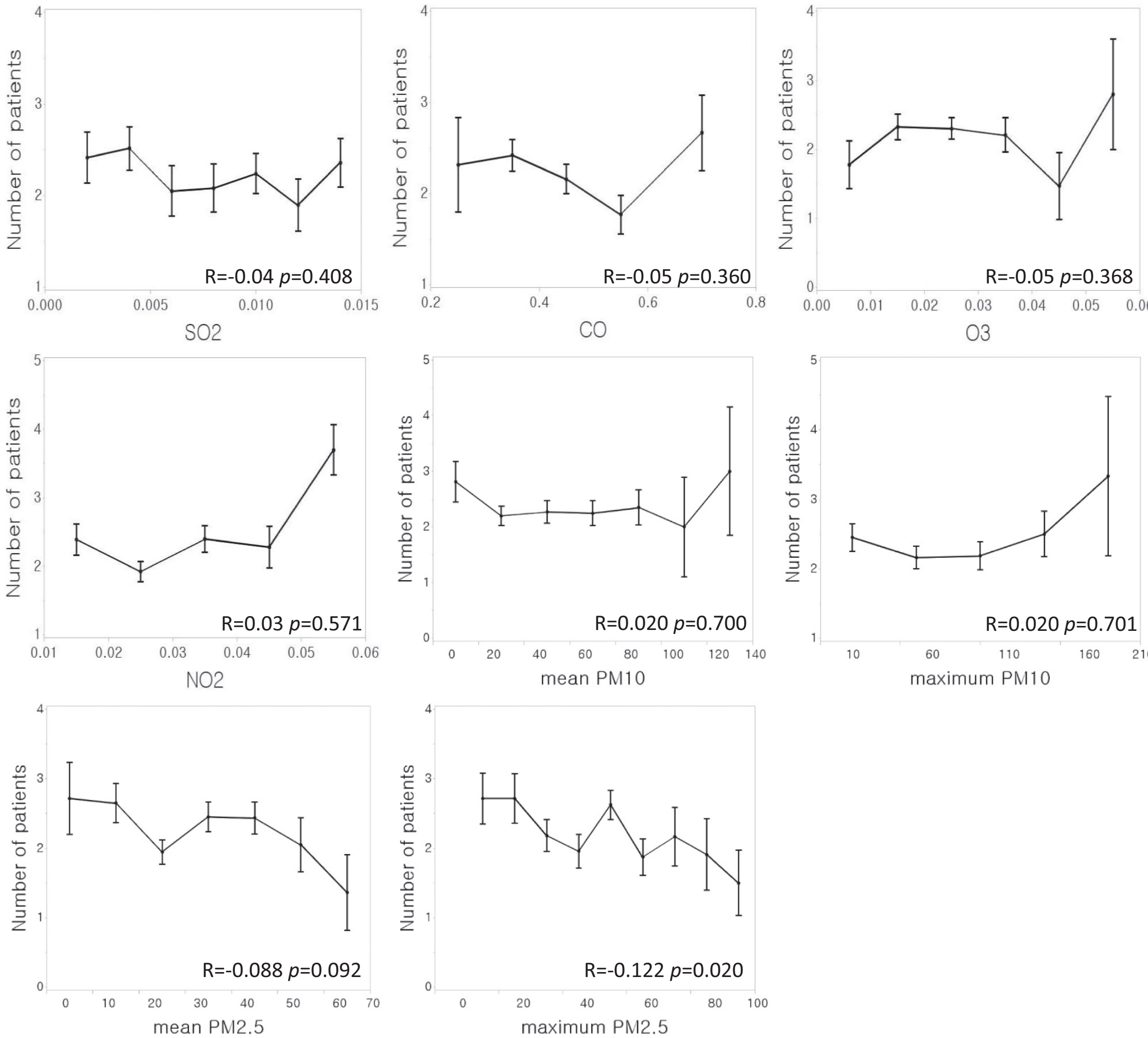

Fig. 4. Relationships between daily numbers of sudden sensorineural hearing loss patient admissions and air pollution including particulate matter levels. Maximum PM2.5 was negatively correlated with the number of patient admissions (R = −0.122, p = 0.020).
SSNHL, sudden sensorineural hearing loss; PM, particulate matter.

definitive histologic evidence has emerged indicating that vascular problems are the cause of SSNHL [10,11]. In the presence of diabetes mellitus, a risk factor for vascular related disease, SSNHL is more common and has been reported to be more severe [12]. However, in that study there was no significant correlation between smoking and hypertension. In a study conducted in Taiwan, it was reported that the risk of stroke within 5 years increased in SSNHL patients [13]. Vascular problems play a role in the development of SSNHL; however, there is no substantial evidence on this and thus vascular problems cannot be considered a common cause of SSNHL [2].

Many studies have investigated associations between meteorological factors and SSNHL. In a previous SSNHL study conducted in the Republic of Korea, the occurrence of SSNHL was significantly higher in March and April, and it was correlated with daily temperature range, wind velocity, and PM10 level [14]. In that report, it was suggested that the occurrence of SSNHL is associated with upper respiratory infection. Seo et al. [15] reported that SSNHL onset was significantly associated with the mean and maximum wind speed in a study investigating meteorological factors and SSNHL onset. In a SSNHL study in Taiwan that included 9267 patients, the incidence of disease was found to be seasonal, and it occurred most frequently in autumn [16]. Conversely, in another study investigating the effects of meteorological factors on SSNHL including 8712 people in Taiwan, no significant relationship between monthly SSNHL incidence rates and weather conditions was found [17]. Other studies have reported that the occurrence of SSNHL and meteorological factors were not significantly associated [18,19]. In a tertiary care center in New York, there was no significant difference in the monthly incidence of SSNHL during the 3-year period, and there was no significant seasonal distribution in the patient group with upper respiratory infection before their SSNHL episode [20].

In addition to studies on SSNHL and meteorological factors, there are indications that meteorological factors may affect various other diseases. In research conducted in the UK, atmospheric pressure and humidity were found to be associated with symptom exacerbation in Meniere's disease [21]. There are reports that there may be changes in viral infection owing to differences in climate [22–24], and the onset of ischemic stroke [25] and acute myocardial infarction have been reported to be associated with low temperature and low atmospheric pressure [26].

Research on the relationship between air pollution(especially PM) and various diseases is now actively being conducted in many fields. In a study investigating the occurrence of respiratory diseases, including acute bronchitis, allergic rhinitis, and asthma, and the associated effects of PM and meteorological factors conducted in the same area as the current study from 2007 to 2010, hospital admission rates for respiratory diseases increased with increasing PM and temperature and with decreasing relative humidity, especially in children and elderly individuals [27]. In a study conducted in Hefei in China, the risk of pediatric upper respiratory tract infection increased by 0.15%, with a 95% confidence interval (CI) of 0.07%–0.23% when PM10 increased by 10 μg/m^3, and for PM2.5 the increase was 0.38% (95% CI 0.17%–0.60%) [28]. In another region in China (Shenzhen), it was reported that increased PM was associated with an increased incidence of children aged < 14 years presenting with acute respiratory infection [29]. In vitro studies reported by Chen et al. [30] suggest that PM may increase susceptibility to infection by increasing bacterial invasion of airway epithelial cells. In an observational study conducted in an urban region in Italy, respiratory syncytial virus bronchiolitis was negatively correlated with temperature and positively correlated with relative humidity, PM10, and PM2.5 [31]. In another report, long-term exposure to PM2.5 reduced resistance to influenza virus, caused injury to lung tissue cells, and downregulated immune defense mechanisms in the lung [32]. Short-term exposure to PM, especially PM2.5, reportedly increases the likelihood of cardiac arrest [33].

The current study was based on the hypothesis that viral infection and microcirculatory problems are involved in the development of SSNHL. Therefore, we hypothesized that increases in PM would be associated with increased numbers of SSNHL patients given the known health effects of PM. According to the report of Korean centers for disease control and prevention, the trend of influenza virus infection in 2015 was similar to that of the previous one, and the trend of other respiratory viral infection was not significantly different from that of the previous one. Therefore, there is no evidence of outbreak of a viral illness that could overwhelm the data [34]. However, in statistical analysis, SSNHL only exhibited weak positive correlations with mean wind speed, maximum wind speed and daily sea level atmospheric pressure range. And number of SSNHL patients were negatively correlated with only maximum PM2.5 value. The correlation between wind speed and PM level was also investigated, because PM level may have decreased when wind speed increased. However, there was no such negative correlation.

The current study has few limitations. First, further statistical analysis is required in the form of a new model that excludes interference between each meteorological factor. The analysis of climate requires various parameters to be considered. In this study, the effects of each factor were analyzed together without any compensation. Second, the duration of the study period was relatively short. The analysis only included 1 year because public disclosure of PM2.5 levels began in 2015, and when extracting raw data pertaining to the patients, only 1 year of data could be extracted due to a data capacity consideration. Therefore, further studies with longer duration should be needed after this study. Third, because the patients were included on the basis of a diagnostic code, there was a possibility of underestimation. Patients who were not hospitalized were also excluded from the analysis. Only hospitalized patients were analyzed because it was possible to hospitalize via the emergency room, so as to minimize the bias that might otherwise occur because of missing patient admission information pertaining to weekends or public holidays.

5. Conclusions

Whereas SSNHL admissions were weakly positively correlated with the mean wind speed and maximum wind speed, unexpectedly, there was a weak negative correlation with such admissions and the PM2.5 levels. This differed from the initial hypothesis of the study, that increases in PM levels would be associated with increases in the incidences of SSNHL admissions. Thus, further research incorporating an extended study period and additional statistical analyses is required.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

References

[1] Stachler RJ, Chandrasekhar SS, Archer SM, et al. Clinical practice guideline: sudden hearing loss. Otolaryngol Head Neck Surg 2012;146:S1–35.
[2] Merchant SN, Durand ML, Adams JC. Sudden deafness: is it viral? ORL J Otorhinolaryngol Relat Spec 2008;70:52–60.
[3] The WHO Regional Office for Europe. Health effects of particulate matter. http://www.euro.who.int/_data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf, Accessed date: 2 February 2018.
[4] Kim KH, Kabir E, Kabir S. A review on the human health impact of airborne particulate matter. Environ Int 2015;74:136–43.
[5] Van Dishoeck HA, Bierman TA. Sudden perceptive deafness and viral infection; report of the first one hundred patients. Ann Otol Rhinol Laryngol 1957;66:963–80.
[6] Veltri RW, Wilson WR, Sprinkle PM, Rodman SM, Kavesh DA. The implication of viruses in idiopathic sudden hearing loss: primary infection or reactivation of latent viruses? Otolaryngol Head Neck Surg 1981;89:137–41.
[7] Fukuda S, Chida E, Kuroda T, Kashiwamura M, Inuyama Y. An anti-mumps IgM antibody level in the serum of idiopathic sudden sensorineural hearing loss. Auris Nasus Larynx 2001;28(Suppl):S3–5.
[8] Kobayashi H, Suzuki A, Nomura Y. Unilateral hearing loss following rubella infection in an adult. Acta Otolaryngol Suppl 1994;514:49–51.
[9] Westmore GA, Pickard BH, Stern H. Isolation of mumps virus from the inner ear after sudden deafness. Br Med J 1979;1:14–5.
[10] Schreiber BE, Agrup C, Haskard DO, Luxon LM. Sudden sensorineural hearing loss. Lancet 2010;375:1203–11.
[11] Merchant SN, Adams JC, Nadol Jr. JB. Pathology and pathophysiology of idiopathic sudden sensorineural hearing loss. Otol Neurotol 2005;26:151–60.
[12] Fukui M, Kitagawa Y, Nakamura N, et al. Idiopathic sudden hearing loss in patients with type 2 diabetes. Diabetes Res Clin Pract 2004;63:205–11.
[13] Lin HC, Chao PZ, Lee HC. Sudden sensorineural hearing loss increases the risk of stroke: a 5-year follow-up study. Stroke 2008;39:2744–8.
[14] Oh HJ, Choi JY, Cho SI. The relationship of intra-annual distribution of sudden sensorineural hearing loss versus meteorological parameters. Kor J Otorhinolaryngol Head Neck Surg 2014;57.
[15] Seo JH, Jeon EJ, Park YS, Kim J, Chang KH, Yeo SW. Meteorological conditions related to the onset of idiopathic sudden sensorineural hearing loss. Yonsei Med J 2014;55:1678–82.
[16] Wu CS, Lin HC, Chao PZ. Sudden sensorineural hearing loss: evidence from Taiwan. Audiol Neurootol 2006;11:151–6.
[17] Lin HC, Lee HC, Chao PZ, Wu CS. The effects of weather on the incidence of sudden sensorineural hearing loss: a 5-year population-based study. Audiol Neurootol 2006;11:165–71.
[18] Preyer S. Effect of weather on the incidence of sudden deafness. Laryngo-rhino-otologie 1996;75:443–6.
[19] Danielides V, Nousia CS, Bartzokas A, Lolis CJ, Kateri M, Skevas A. Weather conditions and sudden sensorineural hearing loss. BMC Ear Nose Throat Disord 2002;2:2.
[20] Jourdy DN, Donatelli LA, Victor JD, Selesnick SH. Assessment of variation throughout the year in the incidence of idiopathic sudden sensorineural hearing loss. Otol Neurotol 2010;31:53–7.
[21] Schmidt W, Sarran C, Ronan N, et al. The weather and Meniere's disease: a longitudinal analysis in the UK. Otol Neurotol 2017;38:225–33.
[22] du Prel JB, Puppe W, Grondahl B, et al. Are meteorological parameters associated with acute respiratory tract infections? Clin Infect Dis 2009;49:861–8.
[23] Gallerani M, Manfredini R. Seasonal variation in herpes zoster infection. Br J Dermatol 2000;142:588–9.
[24] Lolekha S, Tanthiphabha W, Sornchai P, et al. Effect of climatic factors and population density on varicella zoster virus epidemiology within a tropical country. Am J Trop Med Hyg 2001;64:131–6.
[25] Oberg AL, Ferguson JA, McIntyre LM, Horner RD. Incidence of stroke and season of the year: evidence of an association. Am J Epidemiol 2000;152:558–64.
[26] Wang H, Kakehashi M, Matsumura M, Eboshida A. Association between occurrence of acute myocardial infarction and meteorological factors. J Cardiol

2007;49:31–40.
[27] Jo EJ, Lee WS, Jo HY, et al. Effects of particulate matter on respiratory disease and the impact of meteorological factors in Busan, Korea. Respir Med 2017;124:79–87.
[28] Li YR, Xiao CC, Li J, et al. Association between air pollution and upper respiratory tract infection in hospital outpatients aged 0-14 years in Hefei, China: a time series study. Public Health 2018;156:92–100.
[29] Xia X, Zhang A, Liang S, Qi Q, Jiang L, Ye Y. The association between air pollution and population health risk for respiratory infection: a case study of Shenzhen, China. Int J Environ Res Public Health 2017;14. (pii E950).
[30] Chen X, Liu J, Zhou J, et al. Urban particulate matter (PM) suppresses airway antibacterial defence. Respir Res 2018;19:5.
[31] Nenna R, Evangelisti M, Frassanito A, et al. Respiratory syncytial virus bronchiolitis, weather conditions and air pollution in an Italian urban area: an observational study. Environ Res 2017;158:188–93.
[32] Ma JH, Song SH, Guo M, et al. Long-term exposure to PM2.5 lowers influenza virus resistance via down-regulating pulmonary macrophage Kdm6a and mediates histones modification in IL-6 and IFN-β promoter regions. Biochem Biophys Res Commun 2017;493:1122–8.
[33] Zhao R, Chen S, Wang W, et al. The impact of short-term exposure to air pollutants on the onset of out-of-hospital cardiac arrest: a systematic review and meta-analysis. Int J Cardiol 2017;226:110–7.
[34] Korean Centers for Disease Control and Prevention. Influenza and respiratory virus infection weekly monitoring report, 52nd week, 2015. http://www.cdc.go.kr/CDC/cms/cmsFileSeDownload.jsp?fid=477&cid=123846&fieldName=attach1&index=1&fk=f7ba7f9a1c0a351e32be7cf2b8a08cf13a627a2db11faf4949d3379e5beb8a; December 30 2015, Accessed date: 28 December 2018.