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The association between wind-related variables and stroke symptom onset: A case-crossover study on Jeju Island

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ABSTRACT

Background: Although several studies have investigated the effects of ambient temperature on the risk of stroke, few studies have examined the relationship between other meteorological conditions and stroke. Therefore, the aim of this study was to analyze the association between wind-related variables and stroke symptoms onset.

Methods: Data regarding the onset of stroke symptoms occurring between January 1, 2006, and December 31, 2007 on Jeju Island were collected from the Jeju National University Hospital stroke registry. A fixed-strata case-crossover analysis based on time of onset and adjusted for ambient temperature, relative humidity, air pressure, and pollutants was used to analyze the effects of wind speed, the daily wind speed range (DWR), and the wind chill index on stroke symptom onset using varied lag terms. Models examining the modification effects by age, sex, smoking status, season, and type of stroke were also analyzed.

Results: A total of 409 stroke events (381 ischemic and 28 hemorrhagic) were registered between 2006 and 2007. The odds ratios (ORs) for wind speed, DWR, and wind chill among the total sample at lag 0–8 were 1.18 (95% confidence interval (CI): 1.06–1.31), 1.08 (95% CI: 1.02–1.14), and 1.22 (95% CI: 1.07–1.39) respectively. The ORs for wind speed, DWR, and wind chill for ischemic stroke patients were slightly greater than for patients in the total sample (OR = 1.20, 95% CI: 1.08–1.34; OR = 1.09, 95% CI: 1.03–1.15; and OR = 1.22, 95% CI: 1.07–1.39, respectively). Statistically significant season-specific effects were found for spring and winter, and various delayed effects were observed. In addition, age, sex, and smoking status modified the effect size of wind speed, DWR, and wind chill.

Conclusions: Our analyses showed that the risk of stroke symptoms onset was associated with wind speed, DWR, and wind chill on Jeju Island.

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1. Introduction

Epidemiological studies have shown that negative health outcomes, such as cardiovascular diseases, are related to exposure to extreme weather events and air pollutants. Although these studies have focused on the association between health and environmental exposures, such as weather and air pollution, additional studies considering the time of exposure and regional characteristics are needed. Because adverse health events occur at the location of and during various atmospheric environmental conditions (Xun et al., 2010), temporal and spatial weather and air pollution scales should be combined, as they play an important role in the research methods for populations at risk of cardiovascular diseases.

Cardiovascular diseases typically exhibit a distinct seasonal pattern, and the highest rate usually occurs during the winter period (Chang et al., 2004). Ambient temperature is similarly considered a seasonal factor related to stroke, and both low and high temperatures are associated with higher risks of stroke morbidity and mortality (Wang et al., 2009; Chen et al., 2013). However, with the exception of temperature, a few studies have been conducted assessing the health effects related to other meteorological conditions. For example, a study conducted in Tuscany, Italy examined the association between geopotential height as a substitute of mean surface pressure and all stroke occurrences

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and suggested that ischemic stroke and other stroke types increased nonlinearly in relation to geopotential height (Morabito et al., 2011). In addition, a study conducted in the UK found that a decrease in atmospheric pressure over the preceding 48 h was adversely associated with hemorrhagic stroke admission (Dawson et al., 2008). Similarly, several studies have examined the relationship between cerebrovascular diseases, particularly stroke, and meteorological conditions, and the results suggested a significant association between temperature and barometric pressure (atmospheric pressure), although wind and humidity were not related did not confirm its relevance (Bokonjic and Zec, 1968; Jehle et al., 1994; Chen et al., 1995). In addition, health effects may vary according to the environmental characteristics of the study location. For example, Jeju Island, which is located off the southern coast of the Korean Peninsula and faces the Pacific Ocean, has a humid subtropical climate with year-round strong winds. Even in winter, the temperature rarely falls below the freezing point. In addition, Jeju Island has complex and varied weather phenomena including local heavy rain and fog (Kim et al., 2006; Jeju Regional Meteorological Administration, 2011). Under conditions of mild temperature change, and if air pressure affects the occurrence of various types of stroke, wind may also affect stroke events, as it is caused by variations in atmospheric pressure. Although limited, studies have demonstrated a relationship between wind-chill and stroke admission (Gill et al., 1988). However, to date it has been difficult to establish the relationship between wind and cerebrovascular diseases. This is mostly likely because the wind speed in a particular region differs seasonally with a stable pattern usually observed by geographic location. However, the nature of the surface and factors influencing the direction and intensity of wind do not usually change. Furthermore, westerlies, polar easterlies, and trade winds blow according to latitude. Therefore, it is unlikely that the effect can be detected using statistical analyses. However, Jeju Island lies an area where the trade winds and the westerlies have much greater volatility. Thus, we hypothesized that unstable patterns, along with weather changes and trough movements in the surrounding areas, would have an influence on health. To verify this hypothesis, we selected Jeju Island because it has an optimum location (33° north, within 100 km of land), turbulent flow year-round, and small temperature changes in a temperate climate area. These small temperature changes lowered the influence of temperature which has been shown to have an association with stroke occurrence. Thus, Jeju Island provided a unique location in which to determine the effect of wind. Therefore, because of its unique meteorological characteristics, the purpose of this study was to investigate the association between 3 wind-related variables (wind speed, the daily wind speed range (DWR), and the wind chill index) and stroke onset on Jeju island. We also assessed the modification effect of the wind-related variables according to age, sex, smoking status, season, and type of stroke.

2. Materials and method

2.1. Study population

Stroke events on Jeju Island were registered at the Jeju National University Hospital according to the Korean Stroke Registry guidelines. Data regarding both ischemic and hemorrhagic stroke incidents from January 1, 2006, to December 31, 2007, were recorded up to 7 days after onset. Data regarding the onset date, admission date, discharge date, and elapsed time between onset and admission as well as demographic characteristics such as age, sex, and smoking status were collected. Using the date of onset, we categorized incidents as occurring in the spring (March–May), summer (June–August), fall (September–November), or winter (December–February) as well as the warm period (April–September), or cold period (October–March). This study was approved by the Institutional Review Board of Jeju National University School of Medicine (IRB no. 2012-06-006) and complied with the guidelines outlined in the Declaration of Helsinki.

2.2. Meteorological variables

Weather data captured during the 2006–2007 study period regarding the daily mean temperature (°C), relative humidity (%), and air pressure (hPa) were obtained from the Korean Meteorological Administration. To compute the daily meteorological variables, we used measurements taken from 4 monitoring stations on Jeju Island: one from each of the eastern, western, southern, and northern parts of the island. We then averaged the hourly values in order to acquire the daily values for all variables except for DWR. To obtain DWR, we subtracted the daily minimum wind speed from the daily maximum wind speed. The wind chill index was calculated using the daily mean values of temperature and wind speed according to the formula suggested by the National Oceanic and Atmospheric Administration (NOAA) (2014) as follows:

$$\begin{aligned}\text{Wind chill}\,(^{\circ}\text{F}) &= 35.75 + 0.6215 \times \text{temp}\,(^{\circ}\text{F}) - 35.75 \\ &\quad \times \left(\text{wind speed (mph)}^{0.16}\right) + 0.4275 \times \text{temp}\,(^{\circ}\text{F}) \\ &\quad \times \left(\text{wind speed (mph)}^{0.16}\right).\end{aligned}$$

However, for this study we converted the temperature into Celsius (°C) and the wind speed into meters per second (m/s). Since the wind chill temperature is only calculated for temperatures at or below 50 °F with wind speeds above 3 miles per hour, the wind chill index was not calculated for out-of-range temperatures and wind speeds.

2.3. Other confounders

Daily concentrations for particulate matter $\leq 10\,\mu m$ in aerodynamic diameter (PM_{10}) were determined for ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) from the National Institute of Environmental Research. When 2 or more monitoring stations were located on the island, the average of each atmospheric variable was calculated. During the study period, data for the meteorological variables were collected from 5 monitoring stations while concentrations of air pollutants were collected from 4 monitoring stations. Since the monitoring stations were located across Jeju Island, we computed hourly mean levels for each environmental factor and then daily mean values.

2.4. Statistical analysis

Descriptive analyses were used to assess the distribution of types of stroke (total/ischemic), age (<60 years old/≥ 60 years old), sex (male/female), smoking status (those who had smoked at any time (smokers)/those who had never smoked (nonsmokers)), and temporal characteristics of stroke events (season and day of the week). Meteorological variables and air pollutant concentrations were analyzed for the overall study period and seasonal time periods except for wind chill index. Because the wind chill index was highly correlated with temperature and was predominately available during the cold period, we analyzed the wind chill index during the cold period only (January through March and October through December).

We applied a case-crossover analysis with fixed strata (calendar years and months) based on the time of onset. Data for the

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