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Long-term exposure to air pollution and the risk of suicide death: A population-based cohort study

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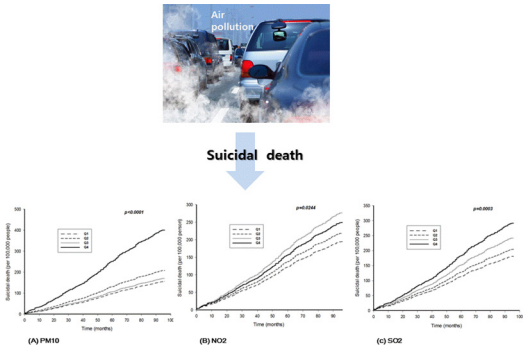
HIGHLIGHTS

- Air pollution is associated with mental health problems.
- We investigated the risk of suicide death on exposure to air pollution.
- Adults exposed to high air pollution had an increased likelihood for suicide death.
- Adults having an underling disease and living in metropolitan areas were more susceptible to air pollution exposure.
- Air pollution may be a risk factor for completed suicide.

GRAPHICAL ABSTRACT



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ABSTRACT

Suicide is a major public health problem. Previous studies have reported a significant association between acute exposure to air pollution and suicide; little attention has been paid to the long-term effects of air pollution on risk of suicide. We investigated whether long-term exposure to particulate matter of ≤10 μm in diameter (PM_{10}), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) would be associated with a greater risk of death by suicide. The study sample comprised 265,749 adults enrolled in the National Health Insurance Service-National Sample Cohort (2002−2013) in South Korea. Suicide death was defined as per ICD-10 code. Data on air pollution exposure used nationwide monitoring data, and individual exposure levels were assigned using geographic information systems. Air pollution exposure was categorized as the interquartile range (IQR) and quartiles. Hazards ratios (HRs) were calculated for the occurrence of suicide death after adjusting for potential covariates. During the study period, 564 (0.2%) subjects died from suicide. Increases in IQR pollutants (7.5 μg/m^3 for PM_{10}, 11.8 ppb for NO_2, and 0.8 ppb for SO_2) significantly increased HR for suicide death [PM_{10}: HR = 3.09 (95% CI: 2.63–3.63); NO_2: HR = 1.33 (95% CI: 1.09–1.64); and SO_2: HR = 1.15 (95% CI: 1.07–1.24)]. Compared with the lowest level of air pollutants (Quartile 1), the risk of suicide significantly increased in the highest quartile level (Quartile 4) for PM_{10} (HR = 4.03; 95% CI: 2.97–5.47) and SO_2 (HR = 1.65; 95% CI: 1.29–2.11) and in the third quartile for NO_2 (HR = 1.52; 95% CI: 1.17–1.96). HRs for subjects with a physical or mental disorder were higher than that those for subjects without the disorder. Subjects living in metropolitan areas were more vulnerable to long-term PM_{10} exposure than those living in non-metropolitan areas. Long-term exposure to air pollution was associated with a significantly increased risk of suicide death. People having underlying diseases or living in metropolitan areas may be more susceptible to high air pollution exposure.

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1. Introduction

Suicide is a major public health problem around the world. An estimated 1.4% of deaths worldwide are a result of suicide, making it the 15th leading cause of death (World Health Organization, 2014). Suicide completion is not just a threat to personal life but also poses a substantial burden on individuals, families, and communities (World Health Organization, 2014). Suicidal behaviors are largely influenced by a variety of factors such as individual traits (i.e., poverty, impulsive aggression, and physical and mental health status), interpersonal conflict, and lack of social supports and networks (Sinyor et al., 2017; Turecki and Brent, 2016).

The possible association between environmental exposure to pollutants and suicide has recently become a concern (Sinyor et al., 2017). One important environmental exposure is air pollution (Bakian et al., 2015; Kim et al., 2010; Kim et al., 2015; Szyszkowicz, 2010; Yang et al., 2011). Historically, air pollution has been a significant contributor to the development of cardiovascular and respiratory illnesses and mortality (Brunekreef and Holgate, 2002; Hoek et al., 2013); emerging evidence also suggests the existence of air pollution-induced mental health problems (Lim et al., 2012; Min and Min, 2017; Oudin et al., 2016; Power et al., 2015; Sass et al., 2017). Exposure to particulate matter of ≤10 μg/m (PM_{10}), particulate matter of ≤2.5 μg/m ($PM_{2.5}$), nitrogen dioxide (NO_2), or ozone (O_3) was significantly associated with the prevalent symptoms of depression and anxiety as well as psychological distress (Lim et al., 2012; Power et al., 2015; Sass et al., 2017). Compared with children and adolescents living in areas with lower air pollution, those living in areas with higher air pollution were more likely to be diagnosed with childhood Attention Deficit Hyperactivity Disorder or to have a dispensed medication for a psychiatric disorder (Min and Min, 2017; Oudin et al., 2016).

Considering the close relationship between air pollution exposure and mental health, it is not surprising that previous studies found that high exposure to air pollutants is significantly associated with an increased risk of completed suicide (Bakian et al., 2015; Kim et al., 2010; Kim et al., 2015; Szyszkowicz, 2010; Yang et al., 2011). A study conducted in South Korea analyzed a total of 4341 suicide cases from data on suicides that occurred in seven metropolitan cities in 2004 (Kim et al., 2010). The authors found that exposures to PM_{10} on lag day 2 and $PM_{2.5}$ on lag day 1 were associated with maximum increases of 9.0% and 10.1% in suicide completion. A US-based study conducted by Bakian et al. (2015) identified a significant association between short-term exposure to air pollutants and suicide completed in Salt Lake County, Utah (Bakian et al., 2015). The adjusted odds for suicide death were 20% for NO_2 on lag day 3 and 5% for $PM_{2.5}$ on lag day 2. A recent Chinese study found a similar relationship between air pollution and suicide death (Lin et al., 2016). Additional studies have documented the seasonal variation (i.e., for summer and cold) in the association between air pollution and the risk of suicide (Szyszkowicz, 2010; Yang et al., 2011).Although most previous studies have demonstrated the short-term effect of air pollutants on completed suicide (Bakian et al., 2015; Kim et al., 2010; Kim et al., 2015; Yang et al., 2011), epidemiologic studies have suggested a potential effect of long-term air pollution on aspects of poor mental health in humans (Kim et al., 2016; Min and Min, 2017; Tzivian et al., 2015). Mice exposed to $PM_{2.5}$for 10 months showed depressed-like affective responses or cognitive impairment, through increased in circulating inflammatory markers or structural changes in hippocampus (Fonken et al., 2011). Based on this circumstantial evidence, examining the association between long-term exposure to air pollution and completed suicide may be a valuable contribution to extend findings from previous research.

In the current study, we hypothesized that long-term exposure to air pollution is associated with a higher risk of suicide. Using a representative cohort of South Koreans, we conducted a prospective population-based study with a 4-year baseline period (2002–2005) and an 8-year follow-up assessment (2006–2013) to examine the association between long-term exposure to airborne particulate and gaseous pollutants and death by suicide in adults. Considering that the health impact of air pollution differs depending on underlying diseases (Bateson and Schwartz, 2004; Mann et al., 2002; Peel et al., 2007), and air quality is different in urban and rural residential areas (Ahn, 2015; Strosnider et al., 2017), we further analyzed the association between air pollution and suicide by the presence of a physical or mental disease and residential areas.

2. Materials and methods

2.1. Data source and study population

The National Health Insurance Service (NHIS) in South Korea provides mandatory social insurance programs for the entire population through government subsidies. The NHIS is the source of nearly all medical data serviced in healthcare facilities including medical examinations and treatment, prescriptions, personal information, and diagnostic codes, as per the International Classification of Diseases (ICD).

The NHIS-National Sample Cohort (NHIS-NSC) is a population-based cohort extracted from the NHIS database (project number: NHIS-2016-2-0081). The NHIS-NSC was constructed by a stratified random sampling design using age, gender, income, residential area, and annual medical expenses to ensure representativeness of the South Korean population. A total of 1,025,340 subjects who account for approximately 2.2% of the total eligible population, comprised the cohort in 2002; these subjects were followed-up until 2013 (Lee et al., 2016).

From the NHIS-NSC, we initially included 746,816 subjects who were aged ≥20 years in 2002. We excluded adults who had incomplete data on address and income (n = 22,878); the remaining population consisted of 723,938 subjects. Of these, approximately 37% had completed at least one medical examination and questionnaires on health behaviors (i.e., exercise, smoking status, and alcohol consumption), and so 458,189 subjects were excluded for the current study. A total of 265,749 adults were included for the final analysis. The study protocol was approved by the Institutional Review Board of Seoul National University Hospital. Informed consent was exempted by the committee.

2.2. Variables

As the main outcome variable, suicide death was defined as "death arising from an act inflicted upon oneself with the intent to kill oneself". Death due to suicide was defined as ICD-10 codes X60-X84.

Demographic characteristics, health behaviors, and the presence of mental and physical diseases were gathered as baseline characteristics of the study population in 2002–2005. Demographic variables included age in 10-year increments (20–29, 30–39, 40–49, 50–59, 60–69, 70–79, or ≥80 years), sex (male or female), residential area (metropolitan or non-metropolitan), and household income relative to the median (<25%, 25–50%, 50–75%, or >75%). Body mass index (BMI) was calculated as an individuals' weight in kilograms divided by height in meters squared, and was categorized as a binary variable (<25.0 or ≥25.0 kg/m^2). Health behaviors included exercise (yes or no), smoking experiences [no (never smoked) or yes (previously or currently smoker)], and alcohol consumption (yes or no). Disease status was defined as having a physical or mental disease potentially affecting the risk of suicide (Bostwick and Pankratz, 2000; Bronisch and Wittchen, 1994; Juurlink et al., 2004; Palmer et al., 2005; Scott et al., 2010). Physical health status was based on the Charlson comorbidity index (CCI) developed by Quan et al. (2005), in which the score ≥ 1 was classified as the presence of physical diseases (Quan et al., 2005). Mental health problems were defined as psychological conditions including anxiety, depression, major affective disorder, and schizophrenia (Bostwick and Pankratz, 2000; Bronisch and Wittchen, 1994; Palmer et al., 2005). The presence of psychiatric conditions was diagnosed by family physicians or general practitioners and specialist physicians in a hospital or

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