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Ambient air pollution and completed suicide in 26 South Korean cities: Effect modification by demographic and socioeconomic factors

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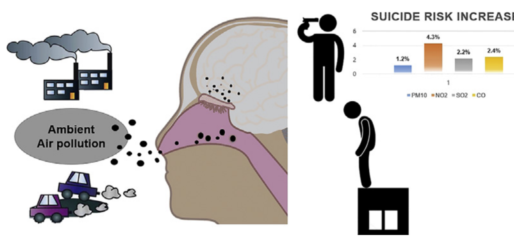
HIGHLIGHTS

- Limited evidence exists on association of air pollution exposure with suicide risk.
- We evaluated effect modification by demographic and socioeconomic factors.
- Air pollution exposure increased the risk of suicide in 26 South Korean cities.
- The effect was greater in old, lowly educated, white-collar, and married people.

GRAPHICAL ABSTRACT



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ABSTRACT

Air pollution has been recently associated with suicide mortality. However, limited studies have examined possible effect modification of the association by various demographic and socioeconomic factors, despite their crucial roles on suicide risk. In 73,445 completed suicide cases from 26 South Korean cities from 2002 to 2013, we studied the association of suicide risk with exposure to particles <10 μm (PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO), using a city-specific conditional logistic regression analysis with a case-crossover design. Random effects meta-analysis was used to pool the results. We considered a delayed effect of air pollution by constructing lags of up to 7 days. We explored effect modification by demographic and socioeconomic factors (sex, age, education level, job, and marital status) as well as place of death, method of suicide, and season, through stratified subgroup analyses. Among five pollutants, NO_2 showed the strongest association at immediate lags (percent change in odds ratio; PM_{10}: 1.2% [95% CI, 0.2%, 2.3%]; NO_2: 4.3% [95% CI, 1.9%, 6.7%]; SO_2: 2.2% [95% CI, 0.7%, 3.8%]; O_3: 1.5% [95% CI, −0.3%, 3.2%]; and CO: 2.4% [95% CI, 0.9%, 3.8%] per interquartile range increase at lag0). In subgroup analyses by socioeconomic factors, stronger associations were observed in the male sex, the elderly, those with lower education status, white-collar workers, and the married; the largest association was an 11.0% increase (95% CI, 4.1%, 18.4%) by NO_2 among white-collar workers. We add evidence of effect modification of the association between air pollution exposure and suicide risk by various demographic and socioeconomic factors. These findings can serve as the basis for suicide prevention strategies by providing information regarding susceptible subgroups.

1. Introduction

The World Health Organization (WHO) has estimated that over 800,000 people die by suicide annually and that suicide is the second

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leading cause of death among people aged 15–29 years worldwide (WHO, 2016). Although WHO has recognized suicide as a public heath priority and encouraged countries to strengthen comprehensive prevention strategies (WHO, 2016), the suicide rate in South Korea has remained high for decades. In 2013, the suicide rate in South Korea was 29.1 per 100,000 population, ranking first among developed countries (OECD, 2015); furthermore, suicide was the fourth leading cause of death, following cancer, cardiovascular, and cerebrovascular diseases (KOSIS, 2017).

To develop better suicide prevention strategies, it is important to investigate and understand risk factors for suicide. For decades, suicide has been related to multiple risk factors such as social, physical, and psychiatric status, as well as their synergetic effects (Nock et al., 2008; Qin et al., 2003); recently, environmental factors also have reportedly been regarded as risk factors for suicide. While studies on the association of suicide risk with meteorological variables including sunshine and temperature have been widely conducted for decades (Dixon et al., 2007; Page et al., 2007; Petridou et al., 2002; Vyssoki et al., 2014), several recent studies have focused on the association between completed suicide risk and air pollution (Bakian et al., 2015; Biermann et al., 2009; Kim et al., 2010; Kim et al., 2015; Yang et al., 2011). However, there have been limited investigations regarding the effect modification by various demographic and socioeconomic factors on the association between air pollution and suicidal death (Kim et al., 2010; Lin et al., 2016; Ng et al., 2016), although these factors have substantial roles on completed suicide.

In South Korea, two studies have been performed to identify the relationship between air pollution and suicidal death; Kim et al. (2010) examined an association of particles <10 μm (PM_{10}) and particles <2.5 μm ($PM_{2.5}$), with completed suicide in 7 cities, and evaluated possible effect modifications by age, sex, insurance levels, underlying diseases, and season based on data over one year. Kim et al. (2015) assessed an association between weekly suicide rate and weekly levels of 5 air pollutants in 16 regions during 2002–2011, without assessment of effect modification. Although both studies have provided evidence for an effect of air pollution on suicidal death, possible effect modifications by various demographic and socioeconomic factors have not been fully evaluated. Furthermore, these previous studies only evaluated single-pollutant models without considering potential confounding by other air pollutants, although they coexist in real-world conditions.

Therefore, we aimed (1) to examine the association of suicide risk with short-term exposure to five air pollutants (PM_{10}; nitrogen dioxide, NO_2; sulfur dioxide, SO_2; ozone, O_3; and carbon monoxide, CO) in 26 South Korean cities between 2002 and 2013; (2) to comprehensively analyze modifying roles of demographic (sex and age) and socioeconomic (education level, job, and marital status) factors as well as other related factors on the association; and (3) to evaluate two-pollutant models which consider potential confounding by other air pollutants.

2. Materials and methods

2.1. Study population

Data on completed suicide cases occurring in 26 South Korean cities (Table 1) between 2002 and 2013 were obtained from the Death Statistics Database (https://mdis.kostat.go.kr/index.do) of the Korean National Statistical Office (International Classification of Disease, 10th revision [ICD-10] codes X60 to X84). The Death Statistics Database includes the following information: district-level residential address, sex, age (years), education level (five categories), job (10 categories), marital status (unmarried/married/divorced/bereaved), date of death, and place of death (seven categories). The method of suicide was categorized based on ICD-10 codes in 15 categories. The variables were recategorized for analysis except marital status as follows: age (<35, 35–64, or ≥65 years), education level (low: no education or elementary school graduation; middle: middle school or high school graduation; or high: college graduation or higher), job (white collar: administrator, specialized scholar/researcher, engineer, or office worker; sales or service worker; blue collar: farmer or fisherman, mechanic, or laborer; or

Table 1
City-specific descriptive information on the study period, suicide rate, and levels of air pollutants in 26 South Korean cities.[a]

Cities	Study period	Population × 1000 (2010)	No. of suicide per year	Suicide rate per 100,000	No. of monitoring sites	PM_{10} (24-h) percentiles (μg/m^3)		NO_2 (24-h) percentiles (ppb)		SO_2 (24-h) percentiles (ppb)		O_3 (8-h) percentiles (ppb)		CO (8-h) percentiles (0.1 ppm)	
						50	90	50	90	50	90	50	90	50	90
Seoul	2002–2013	9794	2161	22.1	27	49.1	96.4	34.8	53.5	4.7	8.3	25.1	49.4	6.2	11.4
Busan	2002–2013	3415	964	28.2	16	47.3	84.5	21.2	34.6	5.7	9.2	32.9	50.8	4.9	7.8
Daegu	2002–2013	2446	595	24.3	11	47.0	84.9	22.1	37.9	4.8	8.9	31.5	58.2	6.4	11.4
Incheon	2002–2013	2663	709	26.6	11	52.3	95.2	27.1	44.6	6.7	10.7	29.4	51.2	6.4	11.6
Gwangju	2002–2013	1476	314	21.3	5	40.2	77.5	19.2	33.0	3.6	6.2	31.3	54.1	5.9	10.5
Daejeon	2002–2013	1502	359	23.9	6	40.4	76.4	19.0	32.3	3.8	7.3	29.5	53.9	6.2	11.8
Ulsan	2002–2013	1083	234	21.6	13	43.4	77.6	19.4	31.1	6.2	10.1	32.8	52.9	5.3	8.4
Suwon	2010–2013	1072	302	28.1	5	44.9	82.0	33.4	55.1	5.1	8.3	29.8	59.9	6.6	11.7
Chuncheon	2010–2013	276	89	32.3	2	46.5	85.4	14.3	30.6	3.0	7.1	34.6	63.8	5.4	12.1
Wonju	2010–2013	311	119	38.2	2	56.8	104.1	20.5	37.0	3.7	10.5	32.4	65.5	7.1	17.8
Gangneung	2010–2013	218	83	38.2	1	36.9	71.2	14.4	23.0	4.3	9.2	31.1	50.7	5.2	8.9
Cheongju	2010–2013	667	188	28.1	4	55.3	98.4	22.8	39.9	3.7	7.3	32.8	62.9	5.2	11.2
Chungju	2010–2013	203	84	41.5	1	39.8	74.2	19.0	36.6	4.0	13.6	36.3	67.0	5.6	18.4
Jecheon	2010–2013	135	58	43.1	1	51.5	97.3	22.8	36.9	4.0	13.4	31.6	61.3	7.2	20.1
Cheonan	2010–2013	575	184	32.0	2	42.6	77.3	21.8	35.8	4.2	7.1	29.1	56.3	6.6	10.3
Jeonju	2010–2013	650	152	23.4	3	48.4	84.4	17.7	30.8	4.2	6.9	28.6	51.0	5.2	8.3
Gunsan	2010–2013	261	93	35.4	3	43.5	80.6	14.0	24.5	4.3	7.8	35.4	55.6	5.3	8.3
Mokpo	2010–2013	250	72	28.8	1	32.3	58.4	15.3	35.6	5.3	9.1	33.3	59.5	5.7	10.2
Yeosu	2010–2013	270	74	27.3	3	32.6	62.8	18.8	31.8	7.4	12.8	36.0	56.5	5.5	8.9
Suncheon	2010–2013	259	42	16.3	1	35.2	64.7	14.3	26.3	4.6	7.4	33.9	54.7	4.4	7.9
Pohang	2010–2013	511	142	27.7	3	43.9	75.3	14.5	22.8	4.8	7.7	32.1	52.8	5.8	8.8
Andong	2010–2013	166	69	41.4	1	35.7	74.2	14.8	26.3	2.6	8.2	35.7	59.4	4.0	8.7
Gumi	2010–2013	403	111	27.5	3	41.9	76.0	16.2	27.0	3.9	6.5	36.5	62.3	5.8	9.2
Changwon	2010–2013	1058	269	25.4	3	41.9	74.7	19.1	35.9	4.2	6.5	39.7	66.1	5.4	8.8
Jinju	2010–2013	338	97	28.7	1	37.2	70.2	14.0	29.9	3.9	7.3	36.1	64.3	5.6	10.0
Jeju	2010–2013	532	126	23.7	2	35.3	75.5	10.0	17.7	2.3	5.3	42.3	59.6	4.4	6.8

[a] For 19 cities except for 7 metropolitan cities among 26 cities, data from 2010 to 2013 were analyzed because the weather data was available only for 2010–2013.