Science of the Total Environment 565 (2016) 271–278

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Association between long-term exposure to air pollutants and prevalence of cardiovascular disease in 108 South Korean communities in 2008–2010: A cross-sectional study

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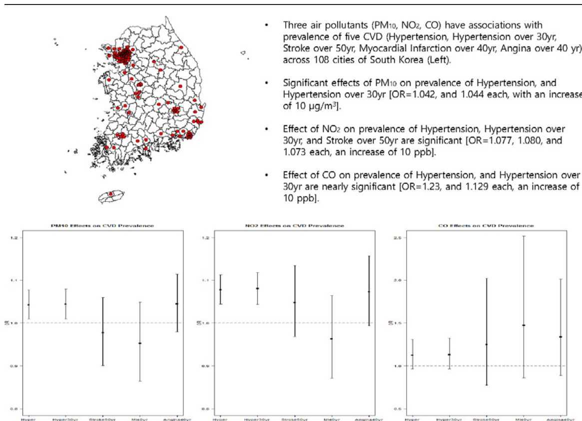
HIGHLIGHTS

- Long-term air pollution exposure was found to be associated with CVD prevalence.
- NO_2 caused an increased risk of CVDs, and CO, PM10 were associated with hypertension.
- Our study included population-based health data with a large sample size.
- The results are important for health-related policies in each community.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 9 October 2015
Received in revised form 27 February 2016
Accepted 22 March 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Air pollution
Long-term effect
Cardiovascular disease
Prevalence
South Korea

ABSTRACT

Air pollution has been linked to cardiovascular disease, which is the leading cause of death worldwide. The aim of this study was to evaluate the epidemiological association between the yearly concentration of air pollution and regional prevalence of cardiovascular disease in South Korea. In this cross-sectional study, data regarding the regional prevalence of cardiovascular disease (i.e., hypertension, stroke, myocardial infarction, and angina) and health behaviors were obtained from the Korean Community Health Survey conducted in 108 communities of South Korea in 2008–2010. Data on carbon monoxide (CO; ppb), nitrogen dioxide (NO_2; ppb), and particulate matter up to 10 μm in size (PM_{10}; $\mu g/m^3$) were collected from the National Institute of Environmental Research. We used a distributed lag model with generalized estimating equations to represent the corrected lag–response and correlation among repeated observations.

Cumulative odds ratios of hypertension, hypertension in those aged >30 years, stroke, and angina with an increase of 10 $\mu g/m^3$ in PM_{10} were 1.042 (95% confidence interval [CI]: 1.009, 1.077), 1.044 (CI: 1.009, 1.079), 1.044 (CI: 0.979, 1.114), and 0.977 (CI: 0.901, 1.059), respectively; a 10 ppb increase in NO_2 was associated with an odds ratio of 1.077 (CI: 1.044, 1.112), 1.08 (CI: 1.043, 1.118), 1.073 (CI: 0.994, 1.157), and 1.047

Abbreviations: BMI, body mass index; CI, confidence interval; CO, carbon monoxide; CVD, cardiovascular disease; DBP, diastolic blood pressure; DLM, distributed lag model; ESCAPE, European Study of Cohorts for Air Pollution Effects; GEE, generalized estimating equation; HR, hazard ratio; KCHS, Korean Community Health Survey; NO_2, nitrogen dioxide; ORs, odds ratios; PM, particulate matter; SBP, systolic blood pressure.

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http://dx.doi.org/10.1016/j.scitotenv.2016.03.163
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(CI: 0.968, 1.134), respectively. A 10 ppb increase in CO was associated with an odds ratio of 1.123 (CI: 0.963, 1.31), 1.129 (CI: 0.963, 1.387), and 1.336 (CI: 0.9887, 2.011) for hypertension, hypertension in patients >30 years, and stroke >50, respectively. We found suggestive evidence of an association between the long-term exposure (i.e., delayed for 5 years) to air pollutants (i.e., PM_{10}, NO_2, and CO) and the regional prevalence of chronic cardiovascular disease (i.e., hypertension, stroke, myocardial infarction, and angina) in 108 communities in South Korea.

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1. Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide (Jemal et al., 2011), and high blood pressure and hypertension are known CVD risk factors (Lawes et al., 2008). Many researchers have shown that long-term exposure to increased concentrations of ambient air pollution is a risk factor for increasing arterial blood pressure (Chen et al., 2015a; Foraster et al., 2014; Fuks et al., 2014) and is associated with hospitalization and death related to CVD (Brook et al., 2004; Dockery et al., 1993). However, the mechanisms, magnitude of these associations, and effects of long-term exposure to pollutants compared to short-term exposure remain uncertain.

In a previous animal study, long-term exposure to low concentrations of ambient particles <2.5 μm ($PM_{2.5}$) altered the vasomotor tone, induced vascular inflammation, and potentiated atherosclerosis (Sun et al., 2005). In epidemiologic studies, exposure to elevated particulate matter (PM) concentrations increases the risk of atherosclerotic plaque rupture, pulmonary and systemic oxidative stress, and inflammation that causes acute CVD (Pope et al., 2004). Therefore, such exposure can induce myocardial infarction (Peters et al., 2001; Zanobetti and Schwartz, 2005) and is associated with the development of ischemic stroke (Hong et al., 2002). Furthermore, short-term exposure to PM and ozone trigger acute arterial vasoconstriction (Brook et al., 2002), and long-term exposure to increased annual average nitrogen dioxide (NO_2) was associated with an increase in systolic blood pressure (SBP) (Foraster et al., 2014).

In Europe and America, there are some studies about the effect of air pollution on health outcomes at a regional level (Beelen et al., 2014; Fuks et al., 2014), but these studies contained cohort data. It is important to study diseases at a regional level because of the differences caused by the level of urbanization. Urbanization is associated with societal and environmental changes throughout a region and affects peoples' lifestyle or the occurrence, mortality, and morbidity of diseases, including CVD, especially in developing countries (Yusuf et al., 2001; Zhai and McGARVEY, 1992). One of the environmental factors affected by urbanization is the concentration of air pollution, such as the higher concentrations of traffic-related air pollutants (e.g., NO_2, and PM up to 2.5 μm in size) in urban areas (Beelen et al., 2014). Therefore, it is very important to investigate the effect of air pollution on health outcomes at a regional level.

Accordingly, the aim of the current cross-sectional study was to evaluate the epidemiological association between the yearly concentration of PM_{10}, NO_2, and carbon monoxide (CO) and the regional prevalence of CVD, particularly, hypertension, stroke, angina, and myocardial infarction in South Korea. Furthermore, we used population-based health data to analyze the regional prevalence of CVD.

2. Material and methods

2.1. Study area and population

Data for this study were obtained from the Korean Community Health Survey (KCHS) conducted in 253 local districts (si/gun/gu) in South Korea in 2008–2010 (Kim et al., 2012b). The KCHS is a nationwide health interview survey conducted by the Korean Centers for Disease Control and Prevention among adults aged >19 years who were living in each district from September to November in 2008–2009 and August to October in 2010 (Kim et al., 2012b). The KCHS used a 2-stage complex, stratified, and probability-cluster sampling process. The 253 Korean local districts are divided into smaller districts (tong/ban/ri). During the first sampling step, the process of selecting a sample area (tong/ban/ri) was conducted by using a probability proportional to the sampling method. In the second sampling step, the sample households in the selected sample area (tong/ban/ri) were selected using a systematic sampling method (Kim et al., 2012b). The KCHS data were weighted, based on the sample design, to be statistically representative of the population (Kim et al., 2012b). To obtain similar confidence levels and accuracies of each indicator in 253 districts, the sample size of each district was set to 900 (Korean Community Health Survey (KCHS), 2015). The KCHS, a repeated survey for 3 years, was conducted to calculate the annual prevalence of disease in each community. Participants were selected randomly every year for the KCHS, which did not contain follow-up data. During the 3 years, 680,202 participants (n = 220,258, 230,715, and 229,229 participants in 2008, 2009, and 2010, respectively) were included in the 2008–2010 KCHS. Indicators about health behaviors (i.e., smoking, alcohol intake, exercise, and nutritional status) and as indicators, prevalence data regarding hypertension, diabetes mellitus, dyslipidemia, CVD, arthritis, osteoporosis, asthma, and metabolic syndrome were calculated as regional ratios standardized by age and sex with 900 as the denominator and the number of participants with these diseases or health behaviors as the numerator (Cho and Kim, 1993; Oh et al., 2013).

2.2. Environmental and prevalence variables

Data for CO (ppb), NO_2 (ppb), and PM up to 10 μm in size (PM_{10}; μg/m^3) were collected from the National Institute of Environmental Research and measured hourly at 200 residential monitoring stations managed consistently from 2003. The locations of the monitoring stations are shown in Fig. 1. In general, one community has one monitoring station; if a community has >2 monitoring stations, the average of these stations were calculated as the representative value of the community. Meteorological data, including outdoor temperature, were obtained from the Korean Meteorological Administration and recorded in 2010 based on a period of 1–24 h each day. In this study, we used the yearly average temperature, which is operationally defined as the mean value from June of the previous year to May. The number of hospitals in each community in 2010 was obtained from Statistics Korea.

A total of 133 communities that have residential monitoring stations were selected; 25 communities were excluded because of missing ≥5% air pollutant data. Finally, a total of 108 communities were included in the analysis. The basic information about these communities is reported in Table S1. In this study, we calculated 5 prevalence ratios, including hypertension, stroke, myocardial infarction, and angina, in those aged >30, >50, >40, and >40 years, respectively, and CVD, which was defined as a self-reported, physician diagnosis. For example, the question regarding hypertension, "Have you ever been diagnosed with hypertension by a physician?" was asked in the survey. After survey gathering, the KCHS-based regional prevalence considered the weighted value by region and sex (Kim et al., 2012b). In CVD, except for hypertension, the KCHS only provided age-stratified prevalence. These prevalence measurements were repeated in 2008–2010 by each community as response variables. A survey with randomly selected participants without

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