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Ambient carbon monoxide and daily mortality in three Chinese cities: The China Air Pollution and Health Effects Study (CAPES)

Renjie Chen [a,b,1], Guowei Pan [c,1], Yanping Zhang [d,1], Qun Xu [e], Guang Zeng [f], Xiaohui Xu [g], Bingheng Chen [a,b], Haidong Kan [a,b,*]

[a] School of Public Health, Key Lab of Public Health Safety of the Ministry of Education, Fudan University, Shanghai, China
[b] G_RI°CE (Research Institute for the Changing Global Environment) and Fudan Tyndall Centre, Fudan University, Shanghai, China
[c] Liaoning Provincial Center for Disease Control and Prevention, Shenyang, China
[d] Taiyuan Municipal Center for Disease Control and Prevention, Taiyuan, China
[e] Department of Epidemiology and Health Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Peking Union Medical College, Beijing, China
[f] Department of Preventive Medicine, School of Management, Beijing University of Chinese Medicine, Beijing, China
[g] Department of Epidemiology and Biostatistics, College of Public Health and Health Professions, University of Florida, Gainesville, FL, United States

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ABSTRACT

Ambient carbon monoxide (CO) is an air pollutant primarily generated by traffic. CO has been associated with increased mortality and morbidity in developed countries, but few studies have been conducted in Asian developing countries. In the China Air Pollution and Health Effects Study (CAPES), the short-term associations between ambient CO and daily mortality were examined in three Chinese cities: Shanghai, Anshan and Taiyuan. Poisson regression models incorporating natural spline smoothing functions were used to adjust for long-term and seasonal trend of mortality, as well as other time-varying covariates. Effect estimates were obtained for each city and then for the cities combined. In both individual-city and combined analysis, significant associations of CO with both total non-accidental and cardiovascular mortality were observed. In the combined analysis, a 1 mg/m^3 increase of 2-day moving average concentrations of CO corresponded to 2.89% (95%CI: 1.68, 4.11) and 4.17% (95%CI: 2.66, 5.68) increase of total and cardiovascular mortality, respectively. CO was not significantly associated with respiratory mortality. Sensitivity analyses showed that our findings were generally insensitive to alternative model specifications. In conclusion, ambient CO was associated with increased risk of daily mortality in these three cities. Our findings suggest that the role of exposure to CO and other traffic-related air pollutants should be further investigated in China.

1. Introduction

Air masses always contain many pollutants in differing amounts, including both particulate matter (PM) and gaseous pollutants. Although the strongest evidence linking air pollutants with adverse health effects thus far is for PM (Pope and Dockery, 2006), many studies have reported associations for gaseous pollutants such as nitrogen dioxide (NO_2) (Samoli et al., 2006), ozone (O_3) (Bell et al., 2004a), sulfur dioxide (SO_2) (Kan et al., 2010), and carbon monoxide (CO). CO is a colorless, odorless, and tasteless air toxin which is produced by incomplete combustion of hydrocarbons. In urban areas, CO is primarily generated by motor vehicle emission. Previously, epidemiologic studies have reported short-term associations of ambient CO with daily mortality and morbidity from cardiovascular diseases (Allred et al., 1989; Dales, 2004; Riojas-Rodriguez et al., 2006; Yang et al., 1998). Recent multi-city analyses conducted in the U.S. and Europe provide further evidence supporting coherence and plausibility of the associations (Bell et al., 2009; Samoli et al., 2007). However, most of these studies were conducted in developed countries.

Coal is still the major source of energy, constituting about 75% of all energy sources. Consequently, air pollution in China predominantly consists of coal smoke, with suspended particulate matter (PM) and sulfur dioxide (SO_2) as the principal air pollutants. In terms of PM and SO_2, China may have the worst air pollution level in the world (Kan et al., 2011). In large cities, however, with the rapid increase in the number of motor vehicles, air pollution has gradually changed from the conventional coal combustion type to the mixed coal combustion/motor vehicle emission type. Also, the characteristics of outdoor air pollution (e.g. air pollution level, and fate and transport of pollutants), meteorological conditions and socio-demographic patterns in China are different from North America and Western Europe. To our knowledge, no prior studies have been carried out to examine the acute health effects of ambient CO in China, or even Asian developing countries.

* Corresponding author at: P.O. Box 249, 130 Dong-An Road, Shanghai 200032, China. Tel./fax: +86 21 6404 6351.
E-mail address: haidongkan@gmail.com (H. Kan).
[1] These authors contributed equally to this work.

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The objective of this paper is to examine the short-term associations between ambient CO and daily mortality in three Chinese cities — Shanghai, Anshan and Taiyuan. This study is a component of the China Air Pollution and Health Effects Study (CAPES) initiated by the China Ministry of Environmental Protection.

2. Materials and methods

2.1. Data

The locations of Shanghai, Anshan and Taiyuan are described in Fig. 1. Shanghai is the economic center and one of the largest cities of China. Anshan is a heavily-polluted industrial city in northeastern China. Taiyuan is the capital city of Shanxi province. Our study areas were restricted to the urban areas of the three cities, due to inadequate air pollution monitoring stations in the suburban areas.

The study periods were 2006 to 2008 for Shanghai, 2004 to 2006 for Anshan, and 2004 to 2008 for Taiyuan. The sources of mortality data were Shanghai Municipal Center of Disease Control and Prevention; Liaoning Provincial Center of Disease Control and Prevention; and Taiyuan Municipal Center of Disease Control and Prevention. The causes of death were coded according to International Classification of Diseases, 10 (ICD-10). The mortality data were classified into deaths due to total non-accidental causes (ICD-10: A00-R99), cardiovascular disease (ICD-10: I00-I99), and respiratory disease (ICD-10: J00-J98).

The sources of air pollutant concentrations were Shanghai Environmental Monitoring Center (6 stations), Anshan Environmental Monitoring Center (2 stations), and Taiyuan Environmental Monitoring Center (9 stations). At each city, the daily concentrations for each pollutant were averaged from the available monitoring results of multiple stations. Automatic continuous monitoring system was set up at each city to measure daily air pollution levels. Air quality indicators included CO, particulate matter with aerodynamic diameter of 10 μm or less (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). 24-hour average concentrations for CO, SO_2, PM_{10}, and NO_2 were calculated. The methods based on light absorbance (Thermo Environmental Instruments Inc., Model 48C), tapered element oscillating microbalance (Thermo Environmental Instruments Inc., TEOM Series 1400a), ultraviolet fluorescence (Thermo Environmental Instruments Inc., Model 43A), and chemiluminescence (Thermo Environmental Instruments Inc., Model 42C) were used for the measurement of CO, PM_{10}, SO_2, and NO_2, respectively. For the calculation of 24-hour mean concentrations, at least 75% of the one-hour values must be available on that particular day. If a station had more than 25% of the values missing for the whole period of analysis, the entire station was excluded from the analysis. In each city, the location of monitoring stations was mandated not to be in the direct vicinity of traffic or of industrial sources, and not to be influenced by local pollution sources and should also avoid buildings, or housing large emitters such as coal-, waste-, or oil-burning boilers, furnaces, and incinerators.

To allow adjustment for the effect of weather conditions on mortality, meteorological data (daily mean temperature and relative humidity) were obtained from one monitoring station at each city.

2.2. Statistical analysis

The CAPES project follows the same protocol as the Public Health and Air Pollution in Asia (PAPA) program of the Health Effects Institute (Wong et al., 2008, 2010). Specifically, the protocol comprises specification for selection of monitoring stations, quality assurance or quality control for the data collection, health outcomes and air pollutants to be included in the analysis. The protocol also included the methods to standardize data management including compilation of daily data. The methods were individualized to suit the local situation, including the specifications for selection of monitoring stations and quality assurance and quality control procedures for data collection on health outcomes and air pollutants to be included in the analysis.

The daily death, air pollution and weather are linked by date and therefore can be analyzed with a time-series design (Zeger et al., 2006). Because counts of daily mortality data in our study approximately follow a Poisson distribution and the relations between mortality and explanatory variables are mostly nonlinear (Dominici et al., 2004), we used overdispersed generalized linear Poisson

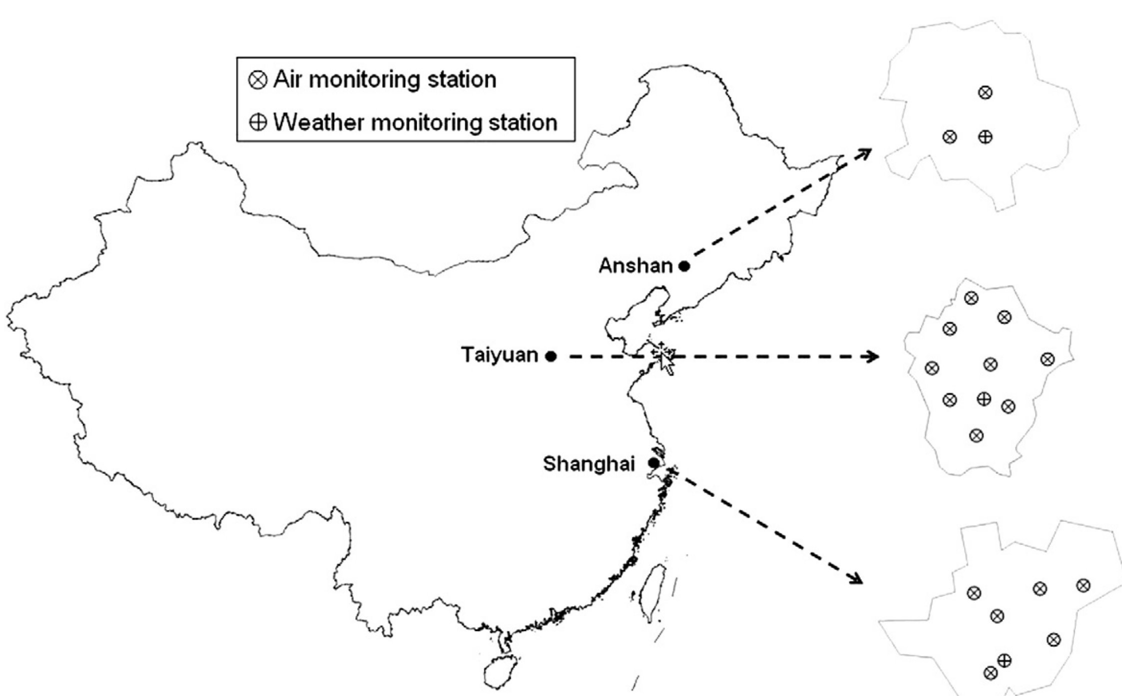

Fig. 1. Locations of air monitoring station and weather monitoring station in Shanghai, Taiyuan and Anshan.