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Long term exposure to air pollution and mortality in an elderly cohort in Hong Kong

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ABSTRACT

Background: Several studies have reported associations between long term exposure to air pollutants and cause-specific mortality. However, since the concentrations of air pollutants in Asia are much higher compared to those reported in North American and European cohort studies, cohort studies on long term effects of air pollutants in Asia are needed for disease burden assessment and to inform policy.

Objectives: To assess the effects of long-term exposure to particulate matter with aerodynamic diameter < 2.5 μm ($PM_{2.5}$), black carbon (BC) and nitrogen dioxide (NO_2) on cause-specific mortality in an elderly cohort in Hong Kong.

Methods: In a cohort of 66,820 participants who were older than or equal to 65 years old in Hong Kong from 1998 to 2011, air pollutant concentrations were estimated by land use regression and assigned to the residential addresses of all participants at baseline and for each year during a 11 year follow up period. Hazard ratios (HRs) of cause-specific mortality (including all natural cause, cardiovascular and respiratory mortality) associated with air pollutants were estimated with Cox models, including a number of personal and area-level socioeconomic, demographic, and lifestyle factors.

Results: The median concentration of $PM_{2.5}$ during the baseline period was 42.2 μg/m^3 with an IQR of 5.5 μg/m^3, 12.1 (9.6) μg/m^3 for BC and 104 (25.6) μg/m^3 for NO_2. For $PM_{2.5}$, adjusted HR per IQR increase and per 10 μg/m^3 for natural cause mortality was 1.03 (95%CI: 1.01, 1.06) and 1.06 (95%CI: 1.02, 1.11) respectively. The corresponding HR were 1.06 (95%CI: 1.02, 1.10) and 1.01 (95%CI: 0.96, 1.06) for cardiovascular disease and respiratory disease mortality, respectively. For BC, the HR of an interquartile range increase for all natural cause mortality was 1.03 (95%CI: 1.00, 1.05). The corresponding HR was 1.07 (95%CI: 1.03, 1.11) and 0.99 (95%CI: 0.94, 1.04) for cardiovascular disease and respiratory disease mortality. For NO_2, almost all HRs were approximately 1.0, except for IHD (ischemic heart disease) mortality.

Conclusion: Long-term exposure to ambient $PM_{2.5}$ and BC was associated with an elevated risk of cardiovascular mortality. Despite far higher air pollution exposure concentrations, HRs per unit increase in $PM_{2.5}$ were similar to those from recent comparable studies in North America.

1. Introduction

Multiple studies have reported associations between long term exposure to air pollutants and adverse health effects (Beelen et al., 2008; Beverland et al., 2012; Gan et al., 2011; Ostro et al., 2015; Ostro et al., 2010; von Klot et al., 2009). Hong Kong is one of the many high-density, high-rise cities in Asia with a significant air pollution issue. In common with many Asian cities, concentrations of air pollutants in Hong Kong are relatively high compared to most European and North American cities, with different composition and exposure patterns. Annual mean $PM_{2.5}$ in Hong Kong was reported by Lee et al. (2006) as 42.2 μg/m^3, in contrast to the range of $PM_{2.5}$ concentrations typically

reported in Western cohort studies of 4.1 to 31 $\mu g/m^3$ (Cohen et al., 2017). Regional secondary particulate smog, which is transported from mainland China, and local street level air pollution serve as the two most important causes for the air pollution problem in Hong Kong (Lee et al., 2006). Regional smog in Hong Kong is formed by a mixture of emissions from traffic, industry and vegetative burning (Lee et al., 2006).

A previous analysis of an elderly cohort in Hong Kong observed that long term exposure to $PM_{2.5}$ was linked with natural cause and cardiovascular mortality (Wong et al., 2015). Wong used satellite-based estimates of $PM_{2.5}$ at a scale of $1\,km \times 1\,km$ and did not assess other pollutants. This study used exposure estimates that may not have captured spatial variability in pollution levels in Hong Kong and may also have been subject to bias due to cloud cover, which may have been more common during period of higher or lower air pollution. Further, the monitoring data that was used in combination with the satellite-based estimates were from a limited number of Government network stations. Recently, land use regression models were developed for Hong Kong, allowing for improved characterization of spatial variability and assessment of additional pollutants (Lee et al., 2017)., In this study, we applied these higher resolution models to the same cohort in order to extend the prior analysis and strengthen the evidence base for epidemiological studies of effects of long term exposure at levels typical of Asian cities.

2. Methods

2.1. Study population

66,820 subjects, accounting for 9% of people who were older than or equal to 65 years old in Hong Kong, were enrolled from July 1998 to December 2001 by the Department of Health Elderly Health Service of the Hong Kong Government. The purpose of the cohort was to promote understanding of aging in Hong Kong where the patterns of common chronic diseases and their determinants may differ from those in the West. The cohort, and its study population, is described in detail by (Schooling et al., 2016). Briefly, Elderly Health Centers (EHC) located in each of the 18 districts in Hong Kong provided health assessments, using standardized and structured interviews, and comprehensive clinical examinations. Information on socio-demographics, lifestyle, and disease history was collected by doctors and registered nurses (Schooling et al., 2016). The health assessment was conducted at the baseline period as well as the follow-up period. There were no specific time points for the follow up health assessment; the participants voluntarily re-enrolled in the Elderly Health Center at least 1 year after their last health assessment. Follow-up compliance was high; nearly 70% of the participants re-enrolled within 3 years of their baseline assessment. Record linkage to the death registry (via Hong Kong Identification Number) was used to examine mortality up to December 31, 2011. The study protocol was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster.

2.2. Mortality outcomes

Deaths were coded according to the *International classification of Diseases, 10th Revision* (ICD-10; WHO 2010) including natural cause mortality (A00–R99), overall cardiovascular disease (I00–I99) and overall respiratory disease (J00–J47 and J80–J99). Subcategories included Ischemic heart disease (IHD) (I20–I25), cerebrovascular disease (I60–I69), Pneumonia (J12–J18) and chronic obstructive pulmonary disease (COPD) (J40–I44 and I47). Participants were excluded if they died within the first year of enrollment. The majority of deaths in Hong Kong occur in hospital, facilitating the consistent and accurate ascertainment of death (Schooling et al., 2016).

2.3. Exposure assessment

The LUR models were derived from street level measurements collected during two sampling campaigns conducted in 2014 and 2015. The model outcomes, including concentration maps, discussion of model performance and interpretation of results are described in detail by Lee et al. (2017).

In brief, two sampling campaigns, corresponding to warm (April 24, 2014 to May 30, 2014) and cool seasons (November 18, 2014 to January 06, 2015), were conducted at 84 sites in Hong Kong for $PM_{2.5}$ and BC. Measurements of NO_2 were collected with passive samplers at ~100 locations. Candidate spatial metrics were selected based on those used in other LUR models (Abernethy et al., 2013; Allen et al., 2012). These predictors included an array of marine (port and shipping), air and road traffic, urban build-up and land use measures as well as information on locations of point and area air pollution sources. The $PM_{2.5}$ LUR ($R^2 = 0.59$, RMSE = $4\,\mu g/m^3$) model included length of expressways, distance to Shenzhen (mainland China), car park density, government and industrial land use as predictors. The BC model ($R^2 = 0.50$, RMSE = $4\,\mu g/m^3$) length of expressways, longitude, car park density, commercial, mixed, residential area, undeveloped land use as predictors. The NO_2 Model ($R^2 = 0.46$, RMSE = $28\,\mu g/m^3$) included length of elevated roads, building volume density, industrial land use and population density as predictors. The differing predictive variables between pollutants, and resulting differing spatial patterns (Lee et al., 2017), highlighted the need for separate assessments for the three pollutants. The concentrations of air pollutants estimated by the LUR models were assigned to all participants according to their geocoded residential addresses at baseline periods. For the entire follow up period, there were only 9.3% participants who changed address. Change in address was accounted for in the exposure estimate assignment.

It should be noted that population density and land use in Hong Kong is very unevenly distributed, with high density around coastal areas and very low density on higher ground, most of which is reserved parkland. The sampling campaign used to develop the LUR model was focused on developed land and roadside locations, which made it more suitable for predicting concentrations in populated areas.

2.4. Back-extrapolation of exposure estimates

Since the LUR model was developed in 2014, prior measured concentrations from 1998 to 2011 were used to extrapolate the LUR model estimates back in time. This back-extrapolation method was based on the assumption that there were no large geographical changes during the study period in Hong Kong. Multiple published analyses have demonstrated stability in spatial variation in air pollution over many years in Western cities (European study of cohorts for Air Pollution Effects, 2012; Gulliver et al., 2013; Wang et al., 2013). While this assumption may not be valid in rapidly developing cities in mainland China, Hong Kong is a relatively geographically stable and well-developed city, therefore we considered this a robust assumption.

First, we calculated the moving average of pollutants concentrations from routine monitoring stations one year before and one year after the recruitment date on a monthly basis for each participant. Second, in line with the ESCAPE methodology, the ratio (for BC, NO_2) or difference (for $PM_{2.5}$) was calculated between the moving average and annual average which covered the measurement period (2014) from routine monitoring stations for each participant. Third, we calculated the baseline back-extrapolated concentrations by multiplying the ratio or the difference and the modelled annual average covering the measurement period (2014). A similar method was also applied when estimating the yearly exposure. We used the concentration of elemental carbon from monitoring stations instead of BC, which was not available for the whole study period.