Science of the Total Environment 646 (2019) 618–624

Contents lists available at ScienceDirect

Science of the Total Environment

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

Urban climate modified short-term association of air pollution with pneumonia mortality in Hong Kong

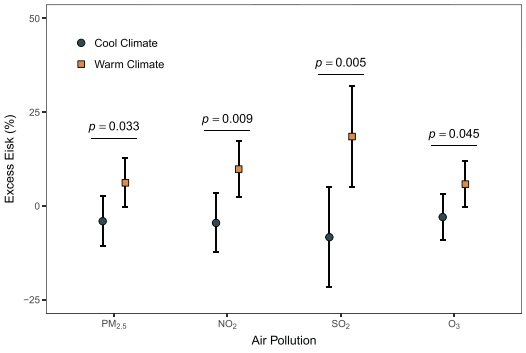
Shengzhi Sun [a,b], Linwei Tian [a,*], Wangnan Cao [c], Poh-Chin Lai [d], Paulina Pui Yun Wong [e], Ruby Siu-yin Lee [f], Tonya G. Mason [a], Alexander Krämer [g], Chit-Ming Wong [a]

[a] School of Public Health, The University of Hong Kong, Hong Kong SAR, China
[b] Department of Epidemiology, Brown University School of Public Health, Providence, RI, USA
[c] Public Health and Healthy Ageing Research Group, Faculty of Dentistry, The University of Hong Kong, Hong Kong SAR, China
[d] Department of Geography, Faculty of Social Sciences, The University of Hong Kong, Hong Kong SAR, China
[e] Science Unit, Lingnan University, Hong Kong
[f] Elderly Health Service, Department of Health, Hong Kong Special Administrative Region, China
[g] Department of Public Health Medicine, School of Public Health, University of Bielefeld, Bielefeld, Germany

HIGHLIGHTS

- Whether warmer climates intensify air pollution-pneumonia mortality is unknown.
- We used urban climatic map to define urban climate.
- Warmer climates worsened association of pneumonia mortality with air pollution in Hong Kong.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 29 May 2018
Received in revised form 5 July 2018
Accepted 20 July 2018
Available online 23 July 2018

Editor: Wei Huang

Keywords:
Air pollution
Pneumonia
Urban climate map
Case-only study
Case-crossover study
Nested case-control study

ABSTRACT

Background: City is becoming warmer, especially in the process of urbanization and climate change. However, it is largely unknown whether this warming urban climate may modify the short-term effects of air pollution.
Objectives: To test whether warmer urban climates intensify the acute mortality effects of air pollution on pneumonia in Hong Kong.
Methods: Participants who died of pneumonia from a prospective Chinese elderly cohort between 1998 and 2011 were selected as cases. Urban climatic (UC) classes of cases were determined by an established Urban Climatic Map according to their residential addresses. UC classes were first dichotomized into cool and warm climates and case-crossover analysis was used to estimate the short-term association of pneumonia mortality with air pollution. We further classified UC classes into climate quartiles and used case-only analysis to test the trend of urban climate modification on the short-term association of pneumonia mortality with air pollution.
Results: Among 66,820 elders (≥65 years), 2208 pneumonia deaths (cases) were identified during the 11–14 years of follow-up. The effects of air pollution for cases residing in the warm climate were statistically significant ($p < 0.05$) higher than those living in the cool climate. There was an increasing linear trend of urban climate modification on the association of pneumonia mortality with NO_2 (nitrogen dioxide) (p for trend = 0.035). Compared to climate Quartile 1 (the lowest), deaths resided in climate Quartile 2, 3, and 4 (the highest) were

* Corresponding author at: School of Public Health, Li Ka Shing Faculty of Medicine, The University of Hong Kong, 7 Sassoon Road, Pokfulam, Hong Kong.
E-mail address: linweit@hku.hk (L. Tian).

https://doi.org/10.1016/j.scitotenv.2018.07.311
0048-9697/

associated with an additional percent change of 9.07% (0.52%, 17.62%), 12.89% (4.34%, 21.43%), and 8.45% (−0.10%, 17.00%), respectively.
Conclusions: Warmer urban climate worsened the acute mortality effects of pneumonia associated with air pollutants in Hong Kong. Our findings suggest that warmer urban climate introduced by climate change and urbanization may increase the risks of air pollution-related pneumonia.

1. Introduction

Pneumonia is one of the most common infectious diseases and is a leading cause of morbidity and mortality worldwide (World Health Organization, 2008). It affects about 450 million people globally and results in approximately 4 million deaths per year, accounting for 7% of the world's total deaths (Ruuskanen et al., 2011). The annual incidence of pneumonia in the elder population is up to four-times than that of the younger group (Janssens and Krause, 2004). With the world is aging rapidly, pneumonia is becoming a major global public health problem.

Air pollution is recognized as the world's largest single environmental problem (Landrigan et al., 2018), and it is one significant risk factor for pneumonia diseases, especially for elders (Zanobetti and Woodhead, 2010). The adverse effects of air pollution on pneumonia morbidity and mortality have been well documented (Faustini et al., 2013; Meng et al., 2012; Nhung et al., 2018; Tian and Sun, 2017). However, the relative risk magnitudes of air pollution effects differ according to geographical regions (Katsouyanni et al., 2009; Kioumourtzoglou et al., 2015). For instance, a large-scale multi-city epidemiological study (Katsouyanni et al., 2009) reported that relative risk estimates for both particulate matter and ozone (O_3) showed substantial heterogeneities among cities in Canada, Europe, and the United States. One of the proposed factors to explain the observed effect heterogeneity of air pollution was the city climate. However, no study has tested this hypothesis by utilizing a reliable tool to characterize the city climate.

With climate change and urbanization, urban is warming rapidly. Pneumonia is a climate-sensitive disease (Sun et al., 2018). It is warranted to test whether this warming climate intensifies the short-term association between air pollution and pneumonia. Although numerous studies reported that temperature (short-term) modified the health effects of air pollution, unlike temperature, people may acclimate to local climate (long-term). In the present study, we aimed to investigate the modification effects of urban climate on the short-term association of air pollution with pneumonia mortality among elders in Hong Kong from 1998 to 2011. We hypothesized that warmer urban climate might increase the risk of pneumonia mortality with air pollution.

2. Methods

2.1. Study population

This study leveraged on a prospective Chinese elderly cohort with a total population of 66,820 older people (65+ years), about 9% of Hong Kong elders, who enrolled at one of the 18 Elderly Health Centres from 1998 to 2001, and were followed up till 31 December 2011 (Schooling et al., 2014). Details of this cohort profile have been described (Schooling et al., 2014). The cohort was linked with the death registration in the Department of Health using the Hong Kong identity card number. We identified pneumonia death by using codes of International Classification of Diseases, 9th revision (ICD-9): 480-487 or ICD-10: J10-J18. Ethics approval was approved by the Ethics Committee of the Faculty of Medicine, The University of Hong Kong and the Hong Kong Department of Health.

2.2. Air pollution and meteorological data

We obtained daily 24-h average concentrations of particulate matter with aerodynamic diameter ≤2.5 μm ($PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3) from ten general monitoring stations from 1998 to 2011 in Hong Kong (Fig. 1). Daily air pollution concentrations were calculated by taking average of the daily air pollution concentrations across the ten monitoring stations. We extracted daily mean ambient temperature and relative humidity for the same study period from the Hong Kong Observatory. The influenza epidemic was defined as a weekly number of positive influenzas A + B isolates ≥4% of the annual total number of positive isolates for at least two consecutive weeks (Chiu et al., 2002; Thach et al., 2010).

2.3. Urban climatic map

Urban Climatic Map (UCMap) constitutes a holistic approach towards understanding the outdoor microclimate conditions. It adequately displays the spatial characteristics and classification of climatopes representing areas of distinct local climates (Planning Department, 2012). Over fifteen countries have developed UCMaps to guide their urban planning (Ren et al., 2011). The methodology of developing the Hong Kong UCMap was described elsewhere (Planning Department, 2012). Briefly, it collated six layers of information, including building volume, topographical height, ground coverage, natural landscape, proximity to openness, and green space. It used Physiologically Equivalent Temperature (PET) (Höppe, 1999), a thermal index and a synergetic indication of human thermal comfort, to calibrate the classification of microclimates. The developed UCMap was verified and calibrated by field measurement and thermal comfort survey study (Planning Department, 2012). Hong Kong was classified into fourteen climatic (UC) classes (Fig. 2). Assuming a mobile radius of 500 m (Requia et al., 2016), we estimated the UC class of each pneumonia death (case) by calculating the area-weighted average of UC classes within 500 m buffer of the case' residential address. Pneumonia cases were then dichotomized into those resided in cool and warm urban climates based on the median (UC class = 0.74) of the UC classes of cases. To investigate the trend of urban climate modification on the association between air pollution and pneumonia mortality, we further divided pneumonia deaths into quartiles according to their UC classes: Quartile 1 (UC classes ranging from −4.10 to −1.59), Quartile 2 (−1.59 to −0.74), Quartile 3 (−0.74 to 0.08), and Quartile 4 (0.08 to 2.70) (Fig. S1).

2.4. Statistical analysis

Time-stratified case-crossover study design was used to estimate the association of air pollution with pneumonia mortality, which is one of the most widely used study designs to investigate the acute health effects of air pollution (Carracedo-Martinez et al., 2010; Jaakkola, 2003). The concept of this approach is similar to a case-control study, except that now cases and controls are the same subject but in different times (Janes et al., 2005; Levy et al., 2001). Each case serves as his/her own control, thus personal characteristics have been controlled by this study design. For each death, the case day is the day of death and the control days are the same weekdays within the same month and year of death (Carracedo-Martinez et al., 2010). Because of