The impact of exposure to air pollution on cognition among elderly people in China

Introduction

While it is examined that there was a strong association between exposure to air pollution and human health, including life expectancy (Ebenstein *et al.*, 2015), mortality (Zhang *et al.*, 2010; Chen *et al.*, 2012), chronic diseases (Chen *et al.*, 2018; Wang *et al.*, 2018), mental health (Zhong *et al.*, 2017), functional health (Sun and Gu, 2008), and self-rated health (Charafeddine and Boden, 2008), knowledge about the potential consequences of air pollution on elderly cognition is limited. Emerging epidemiological research suggests that exposure to air pollution may deteriorate the brain health and functioning (Ham, Zweig and Avol, 2011), but this finding is focused on the young students. It is unclear whether their conclusions support for the whole population, in particular, for the elderly.

Comparing with younger adults, the elderly is more likely to be susceptible to adverse health outcomes associated with air pollution (Zeng *et al.*, 2010). People breathing polluted air are more likely to be subject to oxygen deficiency, which prevents the body from releasing adequate oxygen to brain and then impair the cognitive ability. Also, prior studies have found that there is a strong association between exposure to air pollution and brain inflammation or neuronal dysfunction (Fiordelisi *et al.*, 2017). Those inflammation and neurodegeneration are the main determinants of cognitive deficits and are the risk factors of neurodegenerative diseases such as Alzheimer's disease.

There is increasing evidence that exposure to air pollution may play an important role in cognitive deficits. However, there are few studies on the association between exposure to air pollution and cognitive function among elderly people in China. In this paper, I use a nationally representative sample of older adults to explore the hypothesis that long-term exposure to air pollution is associated with worse cognitive health, even after short-term controlling exposure risk factor and individual/city-level cofounding factors.

Data and Method

Study population

The data used in this study are from the second and third wave of the China Health and Retirement Longitudinal Study (CHARLS) in 2013 and 2015. The CHARLS is a nationally representative of those aged 45 and over in Chinese population since 2011. This dataset is high-quality public micro-database, which can provide detailed demographic, health, economic and cognitive information on individuals and families who are part of the study. This survey collected data from 450 communities/villages in 150 cities, covering 21086 individuals in 12471 households in year of 2015, and 18622 individuals in 10828 households in 2013. However, not every city has the air quality index (AQI) records because most of air quality monitoring stations were established since 2013 and thus, individuals living in those cities without AQI records are excluded from this study. The final sample includes 9503 elderly residents in 2013 and 20787 in 2015.

Dependent variable: Cognition

The dependent variable in this study is cognition characteristics in the CHARLS 2013 and 2015 follow-up survey. Cognition, an important characteristic of mental health, refers to mental process that involve several dimensions, including memory, abstract reasoning and executive function, which is an important ability for elderly people, especially for those who live alone. CHARLS is a sister dataset of Health and Retirement Study, and Survey of Health, Ageing and Retirement in Europe (SHARE). There are two measures of cognition in this study. The first one is memory recall based on a respondent's ability to immediately repeat in any order ten Chinese nouns, just read to them (immediate word recall) and to recall the same list of words 4 minutes later (delayed recall). Recalling answers are marked to mental status score ranged from 0 to 10. The second measure is based on some components of the mental status questions of the Telephone Interview of Cognitive Status (TICS) established to capture intactness or mental status of individuals. In CHARLS, mental status questions contain the following items – serial 7 subtraction from 100 (up to five times) and whether the respondent needed any explanation or used an aid such as paper and pencil, naming today's date (month, day, year, and season), the day of the week, and the ability to redraw a picture shown to him/her. Answers to these questions are aggregated into a single mental status score that ranges from 0 to 11.

Independent Variable: Air Quality Index (AQI)

This study uses the air quality data during the period from 2010 to 2015 from Ministry of Ecology and Environment of China. The measure of air pollution is AQI, which is an integrated nonlinear and dimensionless indicator. Higher value in AQI means more polluted air quality. The computation of AQI is a piecewise linear function of the pollutant concentration, using single air pollutant, e.g., PM2.5, PM10, SO2, NO2, O3, CO etc, to calculate the individual air quality index (IAQI).

To explore the long-term effect of exposure to air pollution, I used the interview date as the end of duration of exposure, and then calculate the mean of AQI for time prior to the interview date: one week (7 days), one month (30 days), one quarter (90 days), and previous one year (365 days) for this study. Furthermore, the standard deviations of AQI of those periods were computed to measure the variation of air quality. To separate the effect of long-term exposure to air pollution from short-term exposure, I use the z-score to capture the variation of short-term, which are better to control the confounding from exposure to air pollution.

Control Variables

To estimate correctly, this study also includes a set of control variables. The first is the demographical variables: sex, age, marital status; the second is socioeconomic variables: education, Hukou (a household registration system in China), and occupation. Of course, some regional confounding factors are included: population density, GDP per person.

Analytic Models

Considering the air pollution data in our study is city-level, multi-level modelling is better for this analysis. To estimate the effect of air pollution more precisely, fixed-effect models are used for this study based on the two waves of CHARLS 2013 and 2015.

Results

Table 1 shows the results of fixed-effect models in terms of recall memory based on CHARLS 2013 and 2015. The variable for long-term exposure is the average of AQI of one year, while the short-term exposure is the z-score of the exposure of a day, a week, a month or a quarter. Besides, in order to explore the interaction effects between long-term exposure and short-term exposure, I also added an interaction term into my models. From Model 1 to Model 4, the difference is the short-term exposure. However, all models show the long-term exposure have negative effects on recall memory. Specifically, when daily exposure is same, with 1-point increase in yearly AQI, the score of recall memory declines 0.004, despite no significance at 5% level. But when the short-term exposure window extended, the effect of long-term exposure to air pollution is significantly negative on recall memory. However, I have not found evidence to support the effects of short-term exposure. Similarly, the interaction effects between long-term and short-term exposure are not significant as well for recall memory.

Table 1. Coefficients and 95% Confidence Intervals of Fixed-effect Models on Memory of the Elderly, China Health and Retirement Longitudinal Study (CHARLS), 2013 & 2015

	Model 1 Day	Model 2 Week	Model 3 Month	Model 4 Quarter
Long-term exposure	-0.004	-0.004#	-0.005*	-0.004#
(a year)	(-0.011 - 0.002)	(-0.007 - 0.000)	(-0.009 - -0.001)	(-0.008 - 0.001)
Short-term exposure	-0.119	-0.060	-0.024	-0.216
	(-0.938 - 0.701)	(-0.547 - 0.428)	(-0.504 - 0.456)	(-0.748 - 0.316)
Long-term * Short-term	0.001	0.001	-0.001	0.001
	(-0.012 - 0.013)	(-0.005 - 0.007)	(-0.007 - 0.005)	(-0.005 - 0.008)
Observations	18,642	18,407	18,407	18,407

a) ** p<0.01, * p<0.05, # p<0.1. All P values are two sides;
b) The category in parentheses is the confidence interval;
c) In all models, control variables include gender, age, education, career, Hukou, marital status, GDP, population density.

Table 2 shows the results of mental status that is a way to measure the cognition. Unlike Table 1, the results of mental status show, a-point increase in the AQI of long-term exposure (1 year) declines 0.010 (95% CI: -0.019 - -0.002), when the short-term exposure is a day. However, when the short-term exposure is longer than a day, I find there are no significant effects of long-term exposure to air pollution.

Table 2. Coefficients and 95% Confidence Intervals of Fixed-effect Models on Mental Status of the Elderly, China Health and Retirement Longitudinal Study (CHARLS), 2013 & 2015

	Model 1 Day	Model 2 Week	Model 3 Month	Model 4 Quarter
Long-term exposure	-0.010*	-0.000	-0.001	-0.003
(a year)	(-0.019 - -0.002)	(-0.005 - 0.005)	(-0.007 - 0.005)	(-0.009 - 0.003)
Short-term exposure	0.936	-0.033	0.0309	0.479
	(-0.192 - 2.064)	(-0.659 - 0.593)	(-0.627 - 0.689)	(-0.243 - 1.200)
Long-term * Short-term	-0.0192*	0.001	-0.001	-0.007
	(-0.0364 - -0.00192)	(-0.006 - 0.009)	(-0.008 - 0.007)	(-0.015 - 0.002)
Observations	11,525	11,361	11,361	11,361

a) ** p<0.01, * p<0.05, # p<0.1. All P values are two sides;
b) The category in parentheses is the confidence interval;
c) In all models, control variables include gender, age, education, career, Hukou, marital status, GDP, population density.

Discussion

Air pollution in China has imposed a great impact on elderly health. This study confirms for China what the association between exposure to air pollution and elderly cognition. In general, the cognition effect of long-term exposure to air pollution remains significant on most models, in particular, using the recall memory to measure the cognition, even after individual and provincial characteristics are controlled. It should be noted that different measures have different effects from air pollution.

It is simply understood why the long-term exposure is a significant variable. The main primary reason is our respondents who are aged over 45 and are more vulnerable to air pollution. Previous studies have shown the long-term exposure to air pollution has higher possibilities to suffer from chronic diseases (Kurt, Zhang and Pinkerton, 2016), which are the important indirect reason for cognition deficits.

However, this study cannot provide any evidence to support the effect of short-term exposure to air pollution on cognition. The reason might be that cognition degradation is due to harmful cumulation of air pollution, and the cumulative effect is more significant than short-term exposure.

In addition, this study also contributes to a strategy to measure and capture the exposure to air pollution, especially to separate the difference of long-term and short-term exposure. Certainly, the causal association of air pollution with cognition has not been examined completely but the detailed mechanism between air pollution and cognition would be discussed in detail in my further studies.

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