Air pollution associated with non-suicidal self-injury in Chinese adolescent students: A cross-sectional study

Weina Liu [a], Hong Sun [a, *], Xin Zhang [b], Qi Chen [a], Yan Xu [a], Xi Chen [c], Zhen Ding [a, **]

[a] *Jiangsu Provincial Center for Disease Control and Prevention, Jiangsu Road 172, 210009 Nanjing, China*
[b] *School of Statistics, Beijing Normal University, 19 XinJieKouWai Street, 100875 Beijing, China*
[c] *Department of Health Policy and Management, Department of Economics, Yale University, 60 College St., New Haven, CT 06520, USA*

HIGHLIGHTS

- PM$_{2.5}$, ozone, and CO are positively associated with non-suicidal self-injury (NSSI) in Chinese adolescent students.
- O$_3$ and CO showed a non-linear association with NSSI.
- Male students in high school were the most susceptible to the effects of PM$_{2.5}$ on NSSI.

ARTICLE INFO

ABSTRACT

Background: Non-suicidal self-injury (NSSI) is a frequent phenomenon in adolescents and is closely related to eventual suicide. Although the effect of air pollution on various diseases has been extensively investigated, no studies examined its effect on NSSI in young students.
Objectives: We investigated the effect of air pollution on NSSI in Chinese students.
Methods: We investigated the incidence of NSSI in the past 12 months in 54 923 Chinese students with an anonymous questionnaire. We assessed the air pollution exposure of each student by the air quality matched with their schools, which were calculated by the inverse distance weighting method from the environmental monitoring data. We discussed the association between ambient air pollutants and the incidence of NSSI using generalized additive mixed models.
Results: A 10 μg/m^3 increase in the annual moving average concentration of particulate matter with diameters less than 2.5 μm (PM$_{2.5}$) and ozone (O$_3$) was associated with a 13.9 percent and a 10.5 percent increase in the odds ratio (OR) of NSSI, respectively. In addition, a 0.1 mg/m^3 increase in the annual moving average concentration of carbon monoxide (CO) was associated with a 4.8 percent increase in the OR of NSSI. NO$_2$ and SO$_2$ were not related to NSSI. CO and O$_3$ show non-linear effects on NSSI. Male students in high school are the most s to the effects of PM$_{2.5}$ on NSSI.
Conclusions: Our study suggests that increases in PM$_{2.5}$, O$_3$ and CO may increase the incidence of NSSI among adolescent students.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Non-suicidal self-injury (NSSI) refers to the intentional self-inflicted destruction of body tissue without suicidal intention and for purposes not socially sanctioned (Cipriano et al., 2017). NSSI is a recurrent phenomenon in adolescents and is a major public health issue in adolescents (Di Pierro et al., 2012; Kiekens et al., 2016). NSSI is typically used to deal with distressing negative affective states, especially anger and depression, and mixed emotional states. NSSI is closely related to eventual suicide (Gulbas et al., 2015; Morgan et al., 2017). Emerging studies have reported the effects of air pollution on suicides (Casas et al., 2017; Chen and Samet, 2017; Szyszkowicz et al., 2010). However, there is a lack of studies on the effects of air pollution on NSSI.

With rapid economic growth in recent decades, air pollution has been part of the most important environmental issues in China. China is experiencing deteriorating air quality because of emissions

---

* Corresponding author.
** Corresponding author.
E-mail addresses: njmu_sunhong@hotmail.com (H. Sun), jscdc@126.com (Z. Ding).

from conventional energy consumption, vehicle exhaust and industrial production. (Kan et al., 2009). Particulate matter (PM) with aerodynamic diameters < 2.5 μm ($PM_{2.5}$), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide(CO) and nitrogen dioxide (NO_2) are the principal air pollutants in China, and their annual average concentrations are potentially harmful according to World Health Organization (WHO) air quality guidelines. Exposure to relatively high concentrations of pollutants among Chinese residents may help model the potentially highly non-linear dose-response relationship, which is difficult to evaluate, using data from developed nations with much lower level of pollution.

Plausible etiologic factors for NSSI may be divided into two major categories: individual factors (e.g., emotional dysregulation, psychiatric disorders) and environmental factors (e.g., childhood maltreatment, attachment disruption). Some research focused on early childhood traumatic experience found that childhood maltreatment emerged as a predictor of NSSI among adolescents and college students (Auerbach et al., 2014; Wan et al., 2015). A large number of studies have reported the association between air pollution and mental disorders, including depression and suicide (Kim et al., 2010; Szyszkowicz, 2007). The effects of air pollution on these disorders might share some similar mechanism for NSSI. Research with experimental animals has provided evidence of neuropathological effects of exposure to polluted air. Ultrafine particles can reach into the brain (Chen and Samet, 2017) and cause further change in the hormone production of mice (Yokota et al., 2016). Another possible mechanism of air pollution was related to peripheral and central inflammation (Chen and Samet, 2017).

Our study was based on a priori hypothesis that air pollution may affect the incidence of NSSI in youth. Therefore, we surveyed the incidence of NSSI in Chinese adolescent students in 2013, matched with air pollution data, and then analyzed the correlation between long-term air pollution and the incidence of NSSI. The purpose of this study was to identify and assess the effects of air pollution on NSSI.

2. Materials and methods

2.1. Analytical sample and NSSI information

This study evaluated data from 54 923 participants through the 2013 National Youth Health Risk Behaviors investigation (NYHRBI) in Jiangsu Province, located in eastern China, with 80 million residents. Systematic randomized cluster sampling was used to enroll students, and students anonymously completed the National Youth Health Risk Behaviors Questionnaire online. Details of the NYHRBI have been described previously (Liu et al., 2017). All surveys were completed between September 1, 2013 and November 30, 2013. All participation was voluntary, and students provided informed consent prior to completing the anonymous surveys. The dataset was relatively bulky, containing 18 871 middle school students, 23 905 high school students and 12 147 college students. The overall qualification rate for the questionnaire was 84%. NSSI incidence among the participants over the previous 12 months before the survey were assessed by the Function of Self Mutilation (FASM) measure within the questionnaire, which is widely used in clinical interviews and community samples of adolescents with acceptable psychometric properties (Nock and Prinstein, 2005; Tang et al., 2016). This study design was approved by the institutional review board of the Jiangsu Provincial CDC.

2.2. Environment data

Air pollution measures were collected from the hourly air quality report published by the Ministry of Environmental

Protection of China (MEP). The report covers 97 monitoring stations in Jiangsu province, including longitude and altitude information for each station. Five pollutants, including $PM_{2.5}$, CO, NO_2, O_3 and SO_2, were used in our analysis. The geocoded addresses of 268 schools were linked to daily average air pollution concentrations between September 2012 and December 2013. To merge the survey data with the air pollution readings, we calculated the weighted average values of all the monitoring stations within 40 km of the school, where the weights were equal to the inverse of distance between stations and the schools. Air pollution exposure of each student was matched to the data of their school location. Following the Chinese education policy, most of the middle or high school students lived around their schools, no more than 5 km, and most of the college school students lived in their campuses. Therefore, air pollutants data matched with schools could reflect the outdoor exposure of students.

2.3. Statistical analyses

We performed multivariate analysis to estimate the effects of air pollution on NSSI, using the generalized additive mixed models (GAMM) with link function of *logit* and with random effect of school. We expressed the estimated effects of a 10 μg/m^3 or 0.1 mg/m^3 (for CO) increase in the concentration of each individual air pollutant as the percent change in the odds ratios for NSSI. In all models, we included factors that we hypothesized a priori could potentially confound the relationship between air pollution and NSSI. Matching the incidence of NSSI in the past 12 months, we calculated the moving annual average value of five air pollutants, including $PM_{2.5}$, O_3, CO, NO_2 and SO_2.

We established adjusted models, and the fixed variables were gender, household per capita income, mother's education, maltreatment, pocket money and school level. All factors were significant in the models. In order to adjust the non-linear effect of other pollutants, we added smooth parameters in the model, including all the other four pollutants when performing specific analysis for one pollutant. School was treated as random effect in GAMM models. Heterogeneous effects of air pollution were analyzed for three principal class variables, including school level, gender, mother's education and maltreatment. The covariates and fixed effects are the same throughout the analysis. The analyses and exposure-response curves were produced by the GAM function of the *mgcv* package in R software (Wood et al., 2016).

3. Results

3.1. Descriptive statistics

The descriptive statistics on the rate of NSSI, ambient air pollution, and sociodemographic characteristics of the study population (n = 54 923) were shown in Table 1. There were 268 schools took part in this investigation. The rate of NSSI ranged from 5.04% (for colleges) to 11.05% (for high school), with an average of 9.27%, which was similar to the rate of NSSI in middle school (9.74%). There was a similar proportion of males and females (48.08% VS 51.92%). The moving annual average of $PM_{2.5}$ and O_3 was 51.67 μg/m^3 and 61.73 μg/m^3, separately. The average monthly household per capita income was approximately 2500 Chinese yuan ($400). A total of 13.2% mothers of investigated subjects received a college education.

3.2. Effects of air pollution on NSSI of students

Five pollutants were analyzed for their association with NSSI, including $PM_{2.5}$, Ozone, SO_2, NO_2, and CO. We assessed the annual