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Original Research

Impact of ambient fine particulate matter air pollution on health behaviors: a longitudinal study of university students in Beijing, China

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ABSTRACT

Objectives: Poor air quality has become a national public health concern in China. This study examines the impact of ambient fine particulate matter ($PM_{2.5}$) air pollution on health behaviors among college students in Beijing, China.

Study design: Prospective cohort study.

Methods: Health surveys were repeatedly administered among 12,000 newly admitted students at Tsinghua University during 2012–2015 over their freshman year. Linear individual fixed-effect regressions were performed to estimate the impacts of ambient $PM_{2.5}$ concentration on health behaviors among survey participants, adjusting for various time-variant individual characteristics and environmental measures.

Results: Ambient $PM_{2.5}$ concentration was found to be negatively associated with time spent on walking, vigorous physical activity and sedentary behavior in the last week, but positively associated with time spent on nighttime/daytime sleep among survey participants. An increase in the ambient $PM_{2.5}$ concentration by one standard deviation (36.5 $\mu g/m^3$) was associated with a reduction in weekly total minutes of walking by 7.3 (95% confidence interval [CI] = 5.3–9.4), a reduction in weekly total minutes of vigorous physical activity by 10.1 (95% CI = 8.5–11.7), a reduction in daily average hours of sedentary behavior by 0.06 (95% CI = 0.02–0.10) but an increase in daily average hours of nighttime/daytime sleep by 1.07 (95% CI = 1.04–1.11).

Conclusions: Ambient $PM_{2.5}$ air pollution was inversely associated with physical activity level but positively associated with sleep duration among college students. Future studies are warranted to replicate study findings in other Chinese cities and universities, and policy interventions are urgently called to reduce air pollution level in China's urban areas.

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Introduction

Fossil fuel economy, population growth, and industrialization have driven the air pollution worldwide to an unprecedented level.[1,2] Despite falling levels of major air pollutants in developed countries over the past few decades, poor air quality continues to be a substantial public health concern.[3] In the meantime, reducing air pollution has rapidly risen to become a national priority in the world's largest developing economies including China and India.[4,5] One type of air pollution that has received increasing attention is fine particulate matter ($PM_{2.5}$), particles that are less than 2.5 μm in diameter. $PM_{2.5}$ is a mixture of solid and liquid particles suspended in the air that mostly comes from combustion of fossil fuels in the process of heating, power generation, and operating motor vehicles.[6] $PM_{2.5}$ can be effectively inhaled and deposited in the airway and alveolar surfaces, causing health problems.[6] There is growing evidence documenting the adverse health effects of short- and long-term exposure to $PM_{2.5}$, including elevated blood pressure, myocardial infarction and stroke, and respiratory diseases such as asthma and bronchitis.[7–10] $PM_{2.5}$ air pollution has also been an important environmental risk factor for all-cause and disease-specific mortality.[11,12]

Although the adverse effects of air pollution on health outcomes have been extensively documented,[13] much less is known regarding its impact on people's health behavior. Physical inactivity is a leading risk factor for morbidity and mortality worldwide.[14–16] A vast majority of children and adults in both developed and developing countries fall short of the guidelines-recommended physical activity level.[17,18] Ambient air pollution may discourage people from engaging in regular physical activity through several mechanisms. Exposure to air pollutants has been linked to decreased lung function, elevated blood pressure, and other cardiovascular and respiratory symptoms,[7–9] resulting in impaired exercise capacity and performance.[19–21] Smog appearance could discourage people from engaging in outdoor activities.[22] Media alerts of air qualities to inform the public about harmful air pollution may alter people's decisions on physical activity.[23] A few studies linked ambient $PM_{2.5}$ air pollution to decline in exercise performance among healthy athletes.[19–21] However, population-based evidence linking ambient $PM_{2.5}$ and physical activity remains lacking. To our knowledge, a total of three population-based studies examined the relationship between $PM_{2.5}$ and physical activity.[21,23,24] All of them analyzed survey data from the Behavioral Risk Factor Surveillance System, a large cross-sectional survey of US adults older than 18 years.[22–24] Ambient $PM_{2.5}$ concentration was consistently found to be associated with a modest, but measurable, decrease in individuals' leisure-time physical activity.[22–24]

Despite the aforementioned work, two major gaps in the scientific literature remain. First, previous studies exclusively focused on the impact of $PM_{2.5}$ concentration on physical activity in the US, but few studies have examined developing countries such as China. In the US, most counties have already met the national air quality standards of $PM_{2.5}$ concentration levels. Fewer than 10 counties, of the more than 3000 counties in the US, would need to consider local actions to reduce $PM_{2.5}$ to meet the new standard of 12.0 $\mu g/m^3$ by 2020.[25] Given the low $PM_{2.5}$ concentration level in the US, a rather modest impact of ambient $PM_{2.5}$ air pollution on leisure-time physical activity should be anticipated. However, a similar relationship between $PM_{2.5}$ air pollution and physical activity may not hold for highly polluted areas of the world where $PM_{2.5}$ concentration levels are at least ten-fold higher. Second, previous studies analyzed cross-sectional data that were subject to confounding bias due to unobserved differences in individual characteristics. Behavioral change in response to temporal variations in air quality could not be assessed because of data unavailability. A developing country-based study examined the influence of $PM_{2.5}$ air pollution on health behaviors among university retirees in China.[26] High $PM_{2.5}$ concentration was found to discourage retired older adults from engaging in daily physical activities but significantly increase their sleep duration.[26] The strength lied in its longitudinal study design, but the use of a convenience sample confined its external validity.[26]

We repeatedly surveyed freshman cohort in a top-tier national university in China since 2012. In a previous publication, we reported preliminary findings regarding the longitudinal associations between ambient $PM_{2.5}$ concentration and physical activity level, using data from the first freshman cohort admitted to the university in 2012.[27] To date, we have compiled data for all four freshman cohorts admitted in 2012, 2013, 2014, and 2015. In this study, we examined the longitudinal relationship between $PM_{2.5}$ concentration and a set of health behaviors including walking, vigorous physical activity, sedentary behavior, and nighttime/daytime sleep among these four university freshman cohorts over a four-year period from 2012 to 2015. We hypothesized that in response to elevated $PM_{2.5}$ air pollution, study participants reduced their outdoor activities such as walking and vigorous physical activity, but increased their sedentary behavior and sleep duration.

Methods

Survey setting

A paper-based health survey is conducted on a regular basis during students' freshman year at the Tsinghua University. The survey includes questions regarding one's sociodemographics, physical and mental health condition, and health and risk behavior. Survey participation is mandatory. All freshmen are required to complete the survey. The survey is administered in class by faculty, and all freshmen take the survey within a 1-week time window. The same survey was administered four times within the freshman year among the newly admitted undergraduate cohort entering in 2012 (Wave 1: September 24th, 2012; Wave 2: November 11th, 2012; Wave 3: March 5th, 2013; and Wave 4: May 5th, 2013), three times among the cohort entering in 2013 (Wave 1: September 23rd, 2013; Wave 2: December 16th, 2013; and Wave 4: May 12th, 2014), three times among the cohort entering in 2014 (Wave 1: October 13th, 2014; Wave 3: March 2nd, 2015; and Wave 4: May 11th, 2015), and twice among the cohort entering in 2015

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