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Original Research

# Ambient fine particulate matter air pollution and leisure-time physical inactivity among US adults

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ABSTRACT

*Objectives:* There is mounting evidence documenting the adverse health effects of short- and long-term exposure to ambient fine particulate matter ($PM_{2.5}$) air pollution, but population-based evidence linking $PM_{2.5}$ and health behaviour remains lacking. This study examined the relationship between ambient $PM_{2.5}$ air pollution and leisure-time physical inactivity among US adults 18 years of age and above.

*Study design:* Retrospective data analysis.

*Methods:* Participant-level data ($n$ = 2,381,292) from the Behavioral Risk Factor Surveillance System 2003–2011 surveys were linked with Wide-ranging Online Data for Epidemiologic Research air quality data by participants' residential county and interview month/year. Multilevel logistic regressions were performed to examine the effect of ambient $PM_{2.5}$ air pollution on participants' leisure-time physical inactivity, accounting for various individual and county-level characteristics. Regressions were estimated on the overall sample and subsamples stratified by sex, age cohort, race/ethnicity and body weight status.

*Results:* One unit ($\mu g/m^3$) increase in county monthly average $PM_{2.5}$ concentration was found to be associated with an increase in the odds of physical inactivity by 0.46% (95% confidence interval = 0.34%–0.59%). The effect was similar between the sexes but to some extent (although not always statistically significant) larger for younger adults, Hispanics, and overweight/obese individuals compared with older adults, non-Hispanic whites or African Americans, and normal weight individuals, respectively.

*Conclusions:* Ambient $PM_{2.5}$ air pollution is found to be associated with a modest but measurable increase in individuals' leisure-time physical inactivity, and the relationship tends to differ across population subgroups.



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## Introduction

Air pollution continues to be a significant public health concern despite falling levels of major pollutants in developed countries.[1] One type of air pollution that has received much attention in the past two decades 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/or 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.[2] $PM_{2.5}$ can be effectively inhaled and deposited in the airway and alveolar surfaces, causing health problems. There is mounting 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.[3–6] $PM_{2.5}$ air pollution has also been an important environmental risk factor for all-cause and disease-specific mortality.[7,8]

Although the adverse effects of $PM_{2.5}$ on health conditions have been well established, much less is known regarding its impact on health behaviour. Physical inactivity is a major cause of morbidity and mortality in the US and worldwide.[9–11] A majority of US adults failed to meet the 2008 Physical Activity Guidelines for Americans.[12] A few studies linked ambient $PM_{2.5}$ air pollution to decline in exercise performance among healthy athletes.[13–15] However, population-based evidence linking ambient $PM_{2.5}$ and physical activity remains lacking. A literature search revealed only two population-based studies examining the relationship between $PM_{2.5}$ and physical inactivity.[2,16] Wen et al. (2009) examined the association between annual $PM_{2.5}$ levels and self-reported leisure-time physical inactivity among 63,290 US adults residing in 142 counties who participated in the Behavioral Risk Factor Surveillance System (BRFSS) 2001 survey. Roberts et al. (2014) evaluated the cross-sectional association of ambient air pollution with leisure-time physical inactivity among BRFSS 2011 survey respondents. Both studies documented a positive association between $PM_{2.5}$ air pollution and physical inactivity. However, their work used a single year of data and was subject to potential confounding issues due to commonalities in individual characteristics within a residential county. Furthermore, it is unclear whether and to what extent the relationship between $PM_{2.5}$ and physical inactivity differs across population subgroups. Currently, air pollution is not considered as an environmental determinant of physical inactivity and is not incorporated in urban planning in an effort to promote physical activity.[17] This situation could change as evidence from future studies begins to accumulate.

This study examined the relationship between ambient $PM_{2.5}$ air pollution and leisure-time physical inactivity among US adults using repeated cross-sectional data from nationally representative health surveys. Our study contributes to the existing literature in three aspects. First, we used nearly a decade of data (2003–2011) with repeated measures for county- and month-specific ambient $PM_{2.5}$ air pollution whereas previous studies focused on a single-year snapshot. Second, we performed multilevel modelling which permits simultaneous examination of the effects from county-level and individual-level predictors while accounting for potential correlations of individuals within the same residential county (due to similarities in physical environment, weather, local policies, etc.). Finally, we assessed potential population heterogeneities in the relationship by gender, age group, race/ethnicity and body weight status.

## Methods

### *Participants*

Individual-level data came from the Behavioral Risk Factor Surveillance System (BRFSS) 2003–2011 surveys. The BRFSS is a state-based system of annually repeated cross-sectional telephone surveys that collect information on health risk behaviours, preventive health practices, and health care access primarily related to chronic disease and injury. Detailed information about the BRFSS including questionnaires, sampling design and survey datasets can be found on its web portal (http://www.cdc.gov/brfss/).

Among the 3,485,550 adults 18 years of age and above who participated in the BRFSS 2003–2011 surveys, the following individuals were excluded from the analyses: missing data on residential county, 443,765; and missing data on individual characteristics (sex, race, education, marital status, employment status, annual household income, body height/weight, smoking status, asthma status, general health status and disability status), 660,493. The remaining 2,381,292 survey participants were included in the final sample.

### *Measure of physical inactivity*

Self-reported physical inactivity during leisure time was ascertained from answers of 'no' to the interview question, 'During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?'

### *Individual characteristics*

The following individual characteristics were controlled in multilevel logistic regressions: male (female as the reference group), 12 dichotomous variables for age group (25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, and 80 years of age and above, with 18–24 years of age as the reference group), four dichotomous variables for race/ethnicity (non-Hispanic African American, non-Hispanic Asian or Pacific Islander, non-Hispanic other race or multirace, and Hispanic, with non-Hispanic white as the reference group), four dichotomous variables for education attainment (some high school, high school graduate or equivalent, some college or equivalent, and college graduate or higher, with primary school or lower as the reference group), six dichotomous variables for employment status (unemployed for one year or less, unemployed for over one year, homemaker, student, retired, and unable to work, with employed as the reference group), two indicator variables for marital status (divorced or widowed or separated, and never married, with married as the reference group), seven dichotomous variables for annual household income ($10,001–$15,000, $15,001–$20,000, $20,001–$25,000,

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