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The effects of air pollution on individual psychological distress

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ABSTRACT

This study is the first of its kind to utilize longitudinal, nationally representative panel data from the United States to assess the relationship between exposure to air pollution and reports of psychological distress. Using annual-average measures of air pollution in respondents' census blocks of residence we find that over the period 1999–2011 particulate matter 2.5 is significantly associated with increased psychological distress; this association remains even after controlling for a robust set of demographic, socioeconomic, and health-related covariates. This study suggests that public health efforts to reduce the personal and societal costs of mental illness should consider addressing not only individual characteristics and factors in the social environment, but also underexplored facets of the physical environment such as air pollution.

1. Introduction

It is widely established in the public and environmental health literatures that exposure to air pollution is hazardous to human health (Mosley, 2014). Past research has largely focused on physical health effects: the association of air pollution with various adverse respiratory and cardiovascular disease outcomes has been particularly well documented (Brunekreef and Holgate, 2002; Seaton et al., 1995). However, recent epidemiological and animal toxicology studies also suggest a plausible connection between air pollution and psychological health.

This is an important avenue of investigation since mental illnesses are common in the United States (US) and account for a sizable share of the burden of disease (Murray and Lopez, 1996). According to findings from the 2014 National Survey on Drug Use and Health (NSDUH), nearly one in five Americans ages 18 and older (18.1% or 43.6 million adults) had a mental illness in the past year and 4.1% (9.8 million adults) had a serious mental illness. This has profound implications for individual and population health (Moussavi et al., 2007), mental health care systems, and the economy (Chisholm et al., 2016). Nevertheless, the environmental determinants of mental illness remain only partially understood.

New evidence has emerged regarding the impact of air pollution on the brain and in the pathogenesis of mental illness. Of interest are animal (e.g., rodent and feral dog) and human studies suggesting that air pollution exposure may lead to neuroinflammation, oxidative stress, cerebrovascular damage, and neurodegenerative pathology via several cellular and molecular pathways (Block and Calderón-Garcidueñas, 2009). A separate but related line of research has further implicated neuroinflammation and cerebrovascular damage in the risk and/or exacerbation of certain mental illnesses (e.g., depression) (Anisman and Hayley, 2012; Dantzer et al., 2008; Krishnadas and Cavanagh, 2012; Sneed and Culang-Reinlieb, 2011).

Air pollution has also been associated with the more proximal behavioral determinants of psychological health. In particular, in areas with higher levels of air pollution, people tend to reduce the amount of time they spend outdoors (Bresnahan et al., 1997). Such averting behavior introduces a number of indirect pathways through which air pollution may further induce or worsen psychological distress, including limited exposure to sunlight and subsequent vitamin D deficiency (Wilkins et al., 2006; Anglin et al., 2013), reduced physical activity and/or exercise (Goodwin, 2003; Abu-Omar et al., 2004; Motl et al., 2004), reduced contact with parks and other green space (Sugiyama et al., 2008; Cohen-Cline et al., 2015; Bratman et al., 2015), and social isolation (Broadhead et al., 1983; Biegel et al., 1985; George et al., 1989).

Despite growing empirical justification for investigating the effects of air pollution on psychological health, relatively few studies have done so explicitly. The small body of research in this area has examined

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the association of air pollution with depressive symptoms (Wang et al., 2014; Lim et al., 2012), anxiety (Power et al., 2015), suicide risk (Kim et al., 2010), and associated emergency department visits (Szyszkowicz et al., 2010a, 2010b; Szyszkowicz, 2007). Findings from this work are promising but not conclusive, as many of these studies tend to rely on small samples, utilize inconsistent measures and methodologies (Zijlema et al., 2016), or are limited in demographic (Lim et al., 2012; Power et al., 2015; Kioumourtzoglou et al., 2017), geographic (Wang et al., 2014; Kim et al., 2016; Cho et al., 2014), and/or temporal (Kim et al., 2010) scope. Of the few studies conducted in the US, one found no association between air pollution and depressive symptoms among older adults (Wang et al., 2014), while two others reported pollution effects on anxiety symptoms (Power et al., 2015) and depression (Kioumourtzoglou et al., 2017).

The present study is among the first to assess the impact of air pollution on psychological distress, a global rather than disorder-specific indicator of mental health problems which encompasses depression, anxiety, and other mood disorders, among US adults. Psychological distress can interfere with social functioning and activities of daily living (Drapeau et al., 2012), and has been associated with increased risks of chronic disease and mortality (Weissman et al., 2015; Forman-Hoffman et al., 2014; Russ et al., 2012). We extend past research by utilizing over a decade of nationally-representative data on individual respondents merged with highly resolved temporal and spatial measures of fine particulate matter ($PM_{2.5}$), a mixture of solid particles and liquid droplets that are 2.5 micrometers in diameter and smaller, in respondents' neighborhoods. Given the ubiquitous but often modifiable nature of air pollution exposure, even associations with psychological distress that are of relatively small magnitude have the potential to greatly impact the personal and societal burdens of mental illness.

2. Data and methods

We use individual-level data from the 1999–2011 waves of the Panel Study of Income Dynamics (PSID), a longitudinal, replenishing survey of Americans which began in 1968 as a national probability sample of over 18,000 individuals in approximately 4800 families. As of 2011, the PSID had expanded to include information on the demographic characteristics, socioeconomic position, and health of over 24,000 individuals in nearly 9000 families.

2.1. Sample

The analytic sample for this study comprises 6006 PSID respondents who were interviewed at least once and up to 6 times (mean=3) between 1999 and 2011, years that correspond with our data on psychological distress and air pollution exposure (psychological distress was not assessed in the PSID in 2005). We organize this information into a series of person-period observations, with each observation referring to the two-year period between PSID interviews. In total, respondents contributed 17,974 person-period observations.

2.2. Independent variable

To this dataset, we attach annual-average concentrations of $PM_{2.5}$ in respondents' neighborhoods using the PSID's supplemental Geospatial Match File. $PM_{2.5}$ is defined by particulate size and is derived primarily from combustion: fireplaces or wood stoves, car engines, and coal- or natural gas-fired power plants are all major sources. Between 1999 and 2011, respondents resided in blocks in which the concentration of $PM_{2.5}$ was, on average, 11.34 micrograms per cubic meter ($\mu g/m^3$), with a range of 2.16–24.23 $\mu g/m^3$. For reference, the Environmental Protection Agency's (EPA) annual national safety standard for $PM_{2.5}$ is 12 $\mu g/m^3$. Consistent with nationwide trends, $PM_{2.5}$ in respondents' neighborhoods declined from an average of 13.23 $\mu g/m^3$ to 9.46 $\mu g/m^3$ during our observation window (Fig. 1).

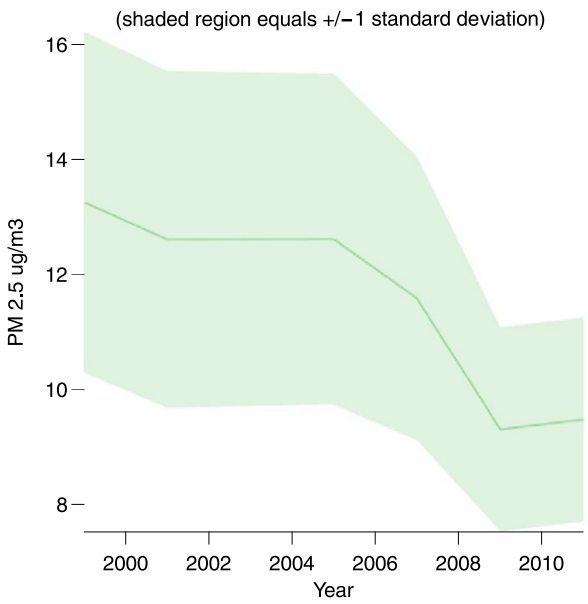

Fig. 1. Mean PM 2.5 decline over time in data sample.

Our measures of neighborhood $PM_{2.5}$ exposure are derived from the EPA's Air Quality System, a database which contains ambient air pollution measurements collected from a nationwide network of monitoring stations. Because these monitoring stations are unevenly distributed across the US and vary across time, we used a combination of land-use regression (LUR) and universal kriging to spatially interpolate reliable air pollution estimates in respondents' neighborhoods. This strategy is described in detail elsewhere (Sampson et al., 2013). In brief, the LUR was based on a database of over 265 geographic covariates, including: population density, total emissions of criteria air pollutants, land use, the normalized difference vegetation index (NDVI), measures of impervious surfaces, distance to and length of major road ways, and distance to commercial zones, airports, railroads, and the like. These variables were measured using a variety of buffer sizes of various radii ranging from 50 m to 30 km. Given such a large number of multicollinear variables, partial least squares (PLS) techniques were used to select only a subset of relevant covariates.

The nation was then divided into three regions – (1) East, (2) Mountain West, and (3) West Coast – and $PM_{2.5}$ prediction models using universal kriging for spatial smoothing were run separately in each region for each year. These models showed high cross-validated R^2, with a national R^2 of 0.88, and well-calibrated predictive intervals. This approach has also been applied in several recent epidemiologic studies of air pollution and health (Chi et al., 2016; Liu et al., 2016; Reding et al., 2015; Chan et al., 2015; Young et al., 2014). In this study, for each interview year, predictions were made at the census block centroid of respondents' census blocks of residence, the smallest unit of geography available in the PSID.

2.3. Dependent variable

Psychological distress is measured with the Kessler 6 (K6) Non-Specific Psychological Distress Scale (Kessler et al., 2003a), a composite instrument of 6 items assessing how often an individual felt sad, nervous, restless, hopeless, worthless, or "that everything was an effort" during the past 30 days. Each item is scored from 0 ("none of the time") to 4 ("all of the time"). Combined scores from the 6 items on this scale range from 0 to 24. According to past research, values of 5–12 may be indicative of moderate mental distress (Prochaska et al., 2012), while scores of 13 and higher have been shown in clinical calibration studies