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The association of air pollution and depressed mood in 70,928 individuals from four European cohorts

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ABSTRACT

Background: Exposure to ambient air pollution may be associated with impaired mental health, including depression. However, evidence originates mainly from animal studies and epidemiological studies in specific subgroups. We investigated the association between air pollution and depressed mood in four European general population cohorts.
Methods: Data were obtained from LifeLines (the Netherlands), KORA (Germany), HUNT (Norway), and FINRISK (Finland). Residential exposure to particles ($PM_{2.5}$, $PM_{2.5}$absorbance, PM_{10}) and nitrogen dioxide (NO_2) was estimated using land use regression (LUR) models developed for the European Study of Cohorts for Air Pollution Effects (ESCAPE) and using European wide LUR models. Depressed mood was assessed with interviews and questionnaires. Logistic regression analyses were used to investigate the cohort specific associations between air pollution and depressed mood.
Results: A total of 70,928 participants were included in our analyses. Depressed mood ranged from 1.6% (KORA) to 11.3% (FINRISK). Cohort specific associations of the air pollutants and depressed mood showed heterogeneous results. For example, positive associations were found for NO_2 in LifeLines (odds ratio [OR] = 1.34; 95% CI: 1.17, 1.53 per 10 $\mu g/m^3$ increase in NO_2), whereas negative associations were found in HUNT (OR = 0.79; 95% CI: 0.66, 0.94 per 10 $\mu g/m^3$ increase in NO_2).
Conclusions: Our analyses of four European general population cohorts found no consistent evidence for an association between ambient air pollution and depressed mood.

1. Introduction

It is well established that exposure to air pollution can lead to a wide variety of adverse health effects (Brunekreef and Holgate, 2002). Air pollution is for example associated with increased risks of pulmonary (Gehring et al., 2013) and cardiovascular disease (Cesaroni et al., 2014a), and mortality (Fischer et al., 2015; Beelen et al., 2014). Exposure to ambient air pollution has also been

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suggested to increase the risk of depressive symptoms, but few epidemiological studies have investigated these effects. So far, mainly short-term studies have been conducted and found relations with increased suicide risk (Kim et al., 2010) and depressive symptoms in Korean populations (Lim et al., 2012), and short-term increases in ambient air pollution were associated with emergency department visits for depression in Canada (Szyszkowicz et al., 2009) and Korea (Cho et al., 2014). However, no evidence for an association between both short- and long-term air pollution exposure and depressive symptoms could be seen in an US study (Wang et al., 2014). Another US study among women reported that long-term and short-term exposure to air pollution was related to anxiety symptoms (Power et al., 2015), which are often comorbid with depression (Lamers et al., 2011).

Recently, studies on air pollution in relation to neuropsychological effects were reviewed. The authors concluded that the two are probably linked, but acknowledged that these results are not conclusive, as the number of studies was limited, and their sample sizes were small (Guxens and Sunyer, 2012). Another limitation in the current literature is the lack of studies investigating the possible confounding and synergistic effects of air pollution and noise on depressed mood. Individuals exposed to traffic related air pollution are probably also exposed to traffic related noise, and both exposures may be related to the pathogenesis of depression (Guxens and Sunyer, 2012). A systematic review of the effects of air pollution and ambient noise on different aspects of mental health concluded that both exposures may be associated with mood disorders (Tzivian et al., 2015). The simultaneous analysis of air pollution and noise has not been undertaken extensively, and is required in future research (Guxens and Sunyer, 2012; Tzivian et al., 2015).

In summary, most prior studies have provided limited evidence for the relation between air pollution and depression, and did not analyze exposure to noise in addition to air pollution. Previous studies were mainly undertaken in Asian (Kim et al., 2010; Lim et al., 2012; Cho et al., 2014) and American populations (Szyszkowicz et al., 2009; Wang et al., 2014), while relations have not yet been studied in Europe. We investigated the association between air pollution exposure and depressed mood in four general population cohorts from Europe, while taking into account exposure to road traffic noise.

2. Methods

2.1. Study population

This study is an analysis of cohort data obtained by BioSHaRE (Biobank Standardisation and Harmonisation for Research Excellence in the European Union), a collaborative project that aims to facilitate harmonization and standardization of data, and the sharing and pooling of data across multiple biobanks and databases. The present study included the BioSHaRE cohorts with information about air pollution exposure and depression prevalence. The cohorts were: LifeLines (three Northern provinces of the Netherlands) (Stolk et al., 2008; Scholtens et al., 2014), HUNT3 (Nord-Trøndelag area, Norway) (Krokstad et al., 2013), KORA (F3 and F4) (Augsburg area, Germany) (Holle et al., 2005), and FINRISK2007 (Helsinki, Vantaa and Turku areas, Finland) (Konttinen et al., 2010). All cohorts are general population based. Air pollution exposure estimation and depressed mood assessments were undertaken within overlapping periods (LifeLines, HUNT), or with a few years in between (KORA, FINRISK). We assume that the spatial contrasts in the measured and modeled annual average levels were stable over these periods (Eeftens et al., 2011). Additional information about the study designs and populations is provided in Table 1. Ethical approval was obtained from the local authorized institutional review boards and written informed consent was obtained from all participants.

2.2. Air pollution exposure assessment

Air pollution estimates for the participant's address locations were derived from two types of land use regression (LUR) models. For LifeLines, KORA, and FINRISK, estimates of particulate matter ($PM_{2.5}$, $PM_{2.5}$ absorbance (reflectance on $PM_{2.5}$ filters, i.e. a marker of black carbon), and PM_{10}) and nitrogen dioxide (NO_2) were calculated using LUR models that were previously developed in ESCAPE (European Study of Cohorts for Air Pollution Effects) (Beelen et al., 2013; Eeftens et al., 2012a). The HUNT study area (Nord-Trøndelag area, Norway) was not included in the ESCAPE project and hence no ESCAPE LUR model was available to be linked to the HUNT cohort. Therefore, for HUNT (and in addition for LifeLines and KORA), estimates of PM_{10} and NO_2 were calculated using Western European-wide (EU-wide) LUR models enhanced with satellite-derived estimates of ground level air pollution (Vienneau et al., 2013). Detailed descriptions of model development and validation can be found in Supplemental Digital Content, including Tables S1 and S2, and elsewhere (Beelen et al., 2013; Eeftens et al., 2012a; Vienneau et al., 2013). Briefly, ESCAPE LUR models were developed for NO_2, $PM_{2.5}$, $PM_{2.5}$ absorbance, and PM_{10} based on estimated annual average concentrations from intensive monitoring campaigns, taking place in each study area between October 2008 and April 2011 (Cyrys et al., 2012; Eeftens et al., 2012b). Measurements were undertaken in three two-week periods in the cold, warm and intermediate season. For each measurement site the annual average concentration was calculated, with adjustment for temporal variation using measurements from centrally located reference sites with year-round measurement data. The air pollution concentrations obtained from the measurement campaign were then used as outcome variables for LUR model development for each of the areas. Geographic Information System (GIS)-derived land use, road network, and other topographic data were used as predictors of the spatial variation in annual average air pollution levels. LUR models were developed locally, but followed a standardized protocol (Beelen et al., 2013; Eeftens et al., 2012a).

The EU-wide model incorporates GIS-derived land use, road network and topographic data, as well as satellite-derived estimates of ground level concentrations for $PM_{2.5}$ (as an indicator of PM_{10}) and NO_2. In these multiple linear regression equations, ambient concentrations of NO_2 and PM_{10} (years 2005–2007) obtained from regulatory monitoring were used as dependent variables. Model development followed the ESCAPE procedure to construct the multiple linear regression equations for Western Europe (17 countries) (Vienneau et al., 2013). The main difference between the ESCAPE and EU-wide models is that the ESCAPE models are region specific, while EU-wide models are developed for a much larger area. ESCAPE models were developed for specific European regions, while the EU-wide models were developed for 17 countries in Western Europe. In addition, monitoring data used in ESCAPE models originated from a monitoring campaign specifically conducted for the ESCAPE-project with monitoring sites selected for this purpose, whereas monitoring data for the EU-wide models were obtained from regulatory monitoring networks.

2.3. Depressed mood assessment

Depressed mood was assessed with standardized face-to-face interviews (LifeLines and KORA) or with questionnaires (HUNT and FINRISK). LifeLines participants were interviewed by trained medical professionals when they visited the research facilities. Depressed mood was assessed with a psychiatric interview (the