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Socioeconomic position and outdoor nitrogen dioxide (NO_2) exposure in Western Europe: A multi-city analysis

Sofia Temam [a,b,c,*], Emilie Burte [a,b], Martin Adam [d,e], Josep M. Antó [f,g,h,i], Xavier Basagaña [f,h,i], Jean Bousquet [a,b,j], Anne-Elie Carsin [f,h,i], Bruna Galobardes [k], Dirk Keidel [d,e], Nino Künzli [d,e], Nicole Le Moual [a,b], Margaux Sanchez [a,b], Jordi Sunyer [f,h,i], Roberto Bono [l], Bert Brunekreef [m,n], Joachim Heinrich [o,p], Kees de Hoogh [d,e,q], Debbie Jarvis [q,r], Alessandro Marcon [s], Lars Modig [t], Rachel Nadif [a,b], Mark Nieuwenhuijsen [f,h,i], Isabelle Pin [u,v,w,x], Valérie Siroux [u,v,w], Morgane Stempfelet [y], Ming-Yi Tsai [d,e], Nicole Probst-Hensch [d,e], Bénédicte Jacquemin [a,b,f,h,i]

[a] INSERM, U1168, VIMA: Aging and Chronic Diseases, Epidemiological and Public Health Approaches, F-94807 Villejuif, France
[b] Univ Versailles St-Quentin-en-Yvelines, UMR-S 1168, F-78180 Montigny le Bretonneux, France
[c] Univ Paris-Sud, Kremlin-Bicêtre, France
[d] Swiss Tropical and Public Health Institute, Basel, Switzerland
[e] University of Basel, Basel, Switzerland
[f] ISGlobal-Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain
[g] Hospital del Mar Medical Research Institute, Barcelona, Spain
[h] Universitat Pompeu Fabra, Barcelona, Spain
[i] CIBER Epidemiología y Salud Pública, Barcelona, Spain
[j] Centre Hospitalo-Universitaire, Montpellier, France
[k] School of Social and Community Medicine, University of Bristol, Bristol, United Kingdom
[l] Department of Public Health and Pediatrics, University of Turin, Turin, Italy
[m] Institute for Risk Assessment Sciences, University Utrecht, Utrecht, The Netherlands
[n] Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, The Netherlands
[o] Institute of Epidemiology, German Research Center for Environmental Health (GmbH), Helmholtz Zentrum München, Neuherberg, Germany
[p] Institute and Outpatient Clinic for Occupational, Social and Environmental Medicine Ludwig Maximilians University, Munich, Germany
[q] Population Health and Occupational disease, National Heart and Lung Institute, Imperial College London, London, United Kingdom
[r] MRC-PHE Centre for Environment and Health, Imperial College London, London, United Kingdom
[s] Unit of Epidemiology and Medical Statistics, Department of Diagnostics and Public Health, University of Verona, Verona, Italy
[t] Public Health and Clinical Medicine, Umea University, University Hospital, Umea, Sweden
[u] IAB, Environmental Epidemiology Applied to Reproduction and Respiratory Health, INSERM, Grenoble, France
[v] IAB, Environmental Epidemiology Applied to Reproduction and Respiratory Health, Univ Grenoble-Alpes, Grenoble, France
[w] IAB, Environmental Epidemiology Applied to Reproduction and Respiratory Health, CHU Grenoble, Grenoble, France
[x] Pédiatrie, CHU Grenoble, Grenoble, France
[y] InVS, French Institute for Public Health Surveillance, Saint-Maurice, France

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ABSTRACT

Background: Inconsistent associations between socioeconomic position (SEP) and outdoor air pollution have been reported in Europe, but methodological differences prevent any direct between-study comparison.
Objectives: Assess and compare the association between SEP and outdoor nitrogen dioxide (NO_2) exposure as a marker of traffic exhaust, in 16 cities from eight Western European countries.
Methods: Three SEP indicators, two defined at individual-level (education and occupation) and one at neighborhood-level (unemployment rate) were assessed in three European multicenter cohorts. NO_2 annual concentration exposure was estimated at participants' addresses with land use regression models developed within the European Study of Cohorts for Air Pollution Effects (ESCAPE; http://www.escapeproject.eu/). Pooled and city-specific linear regressions were used to analyze associations between each SEP indicator and NO_2. Heterogeneity across cities was assessed using the Higgins' I-squared test (I^2).

Abbreviations: ECRHS, European Community Respiratory Health Survey; EGEA, French Epidemiological family-based study of the Genetics and Environment of Asthma; ESCAPE, European Study of Cohorts for Air Pollution Effects; LUR, land use regression; MAUP, modifiable area unit problem; NO_2, nitrogen dioxide; OC, occupational class; PM, particulate matter; SAPALDIA, Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults; SEP, socioeconomic position.

* Corresponding author at: INSERM UMR-S 1168, VIMA: Aging and Chronic Diseases, Epidemiological and Public Health Approaches, 16 Avenue Paul-Vaillant Couturier, F-94807 Villejuif Cedex, France.
E-mail address: sofia.temam@inserm.fr (S. Temam).

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Results: The study population included 5692 participants. Pooled analysis showed that participants with lower individual-SEP were less exposed to NO_2. Conversely, participants living in neighborhoods with higher unemployment rate were more exposed. City-specific results exhibited strong heterogeneity ($I^2 > 76\%$ for the three SEP indicators) resulting in variation of the individual- and neighborhood-SEP patterns of NO_2 exposure across cities. The coefficients from a model that included both individual- and neighborhood-SEP indicators were similar to the unadjusted coefficients, suggesting independent associations.
Conclusions: Our study showed for the first time using homogenized measures of outcome and exposure across 16 cities the important heterogeneity regarding the association between SEP and NO_2 in Western Europe. Importantly, our results showed that individual- and neighborhood-SEP indicators capture different aspects of the association between SEP and exposure to air pollution, stressing the importance of considering both in air pollution health effects studies.

1. Introduction

Environmental inequality refers to a differential distribution of environmental hazards across socioeconomic or socio-demographic groups (Bolte et al., 2012). Historically, research on environmental inequality has emerged in the United States (US) following the Environmental Justice Movement (O'Neill et al., 2003; Morello-Frosch et al., 2011; Evans & Kantrowitz, 2002; Bowen, 2002). Repeatedly, US studies reported that lower socioeconomic or minority groups were more likely to be exposed to higher traffic-related air pollution exposure such as nitrogen dioxide (NO_2) or particulate matter (PM) (Hajat et al., 2015). However, results from US studies cannot be extended to European countries because of very different socio-spatial characteristics, specifically in urban areas (Musterd, 2005). For example, one of the main differences is that in general in most US cities, lower socioeconomic groups tend to live downtown when upper socioeconomic groups reside in the suburbs. In European cities, compared to US, social segregation is lower and lower socioeconomic groups rather live on the outskirts of the city (Musterd, 2005).

In Europe, a rather limited number of studies compared to US had investigated the association between socioeconomic position (SEP) and air pollution, mainly in the UK first and then in other European countries (Hajat et al., 2015; Pye et al., 2008). Inconsistent results have been reported in the European literature (Deguen & Zmirou-Navier, 2010). Some studies reported that populations with low SEP are more exposed to outdoor air pollution (Chaix et al., 2006a; Rotko et al., 2001; Schikowski et al., 2008; Wheeler & Ben-Shlomo, 2005; Brainard et al., 2002) while other studies reported an inverse association (Forastiere et al., 2007; Nafstad et al., 2004; Fernandez-Somoano & Tardon, 2014; Wheeler, 2004). Nonlinear association (higher exposure in middle class) (Havard et al., 2009) and no association (Vrijheid et al., 2012) were also reported. Inconsistent results were also reported within the same country, for instance in France or Spain (Vrijheid et al., 2012; Padilla et al., 2014; Fernández-Somoano et al., 2013; Morelli et al., 2016). However, these studies were difficult to compare with each other because they used different methodologies to assess air pollution exposure or to define SEP (Hajat et al., 2015; Miao et al., 2015). Moreover, most studies relied on ecological data that can raise methodological issues such as ecological fallacy, modifiable area unit problem (MAUP) or spatial autocorrelation (Havard et al., 2009; Jerrett & Finkelstein, 2005). Few studies used individual-level data (i.e. air pollution exposure at residential address and individual-level SEP) or multilevel data (i.e. SEP estimated at individual- and area-level) (Forastiere et al., 2007; Fernandez-Somoano & Tardon, 2014; Llop et al., 2011; Chaix et al., 2006b; Naess et al., 2007; Cesaroni et al., 2010; Goodman et al., 2011). Recent evidence showed the importance of considering SEP at both individual and area levels because they are independently associated with health outcomes (Hajat et al., 2015; Chaix et al., 2006a; Bell et al., 2005a; Stafford, 2003; Diez Roux, 2007).

More generally, the association between SEP and air pollution still needs to be investigated in Europe (Hajat et al., 2015; Miao et al., 2015) as SEP is one of the major potential determinants of variability in the association between air pollution and health (O'Neill et al., 2003; Bell et al., 2005b; Jerrett et al., 2011).

Within the framework of the multicenter European Study of Cohorts for Air Pollution Effects (ESCAPE) (Beelen et al., 2013), we had the opportunity to tackle this research gap using outdoor NO_2 annual concentrations at participants' home addresses estimated from standardized procedures across a large range of European cities (Beelen et al., 2013). The main objective of the present analysis was to test the environmental justice hypothesis that people with lower SEP (defined at both individual and neighborhood level) were more exposed to traffic related air pollution exposure than people with higher SEP in Western Europe.

2. Materials and methods

2.1. Study population

This cross-sectional study included participants of three multicenter epidemiological European cohorts that had previously collaborated together (Boudier et al., 2013) and were involved in the ESCAPE study: the French Epidemiological family-based study of the Genetics and Environment of Asthma (EGEA2) (2003–2007) (Siroux et al., 2009), and two population-based studies: the European Community Respiratory Health Survey (ECRHSII) (1999–2002) (Jarvis, 2002) and The Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults (SAPALDIA2) (2001 − 2003) (Ackermann-Liebrich et al., 2005). Details on each cohort are given elsewhere (Siroux et al., 2009; Jarvis, 2002; Ackermann-Liebrich et al., 2005) and summarized in the supplementary materials. For the three cohorts, information on participants were collected from detailed, standardized and validated questionnaires completed by face-to-face interviews.

Initially, the ESCAPE study included a subsample of the three cohorts ($n = 9556$ participants, Fig. 1) from 20 urban areas of eight Western European countries. Of these 20 areas, we were able to recover homogenized SEP data at individual and neighborhood level for 16 ($n = 5692$ participants: 4002, 1078 and 612 in ECRHS, EGEA and SAPALDIA respectively; Fig. 1) including Norwich, Ipswich (Great Britain; GB); Antwerp (Belgium; BE); Paris, Lyon, Grenoble, Marseille (France; FR); Geneva, (Switzerland; CH); Verona, Pavia, Turin (Italy; IT); Oviedo, Galdakao, Barcelona, Albacete, Huelva (Spain; SP) (Fig. S1). The areas covered by ESCAPE were of substantially different sizes (Table S1) with a range of density population from 152 to 21,154 inhabitants/km^2 (Cyrys et al., 2012). Most of them could be defined as metropolitan areas (large cities with surrounding smaller suburban communities) but some areas were restricted to a single city (municipality). For purposes of clarity, we refer to these different areas as “cities”.