Environment International 70 (2014) 95–105

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Long-term air pollution exposure and diabetes in a population-based Swiss cohort

Ikenna C. Eze [a,b], Emmanuel Schaffner [a,b], Evelyn Fischer [a,b], Tamara Schikowski [a,b,c], Martin Adam [a,b], Medea Imboden [a,b], Ming Tsai [a,b], David Carballo [d], Arnold von Eckardstein [e], Nino Künzli [a,b], Christian Schindler [a,b], Nicole Probst-Hensch [a,b,*]

[a] Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland
[b] University of Basel, Basel, Switzerland
[c] IUF — Leibniz Research Institute for Environmental Medicine, Düsseldorf, Germany
[d] Division of Cardiology, Geneva University Hospital, Geneva, Switzerland
[e] Institute of Clinical Chemistry, University Hospital Zurich, Zurich, Switzerland

ARTICLE INFO

Article history:
Received 3 December 2013
Accepted 16 May 2014
Available online 7 June 2014

Keywords:
Air pollution
Type 2 diabetes
PM_{10}
NO_2
Epidemiology
Association analysis

ABSTRACT

Air pollution is an important risk factor for global burden of disease. There has been recent interest in its possible role in the etiology of diabetes mellitus. Experimental evidence is suggestive, but epidemiological evidence is limited and mixed. We therefore explored the association between air pollution and prevalent diabetes, in a population-based Swiss cohort.

We did cross-sectional analyses of 6392 participants of the Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults [SAPALDIA], aged between 29 and 73 years. We used estimates of average individual home outdoor PM_{10} [particulate matter <10 μm in diameter] and NO_2 [nitrogen dioxide] exposure over the 10 years preceding the survey. Their association with diabetes was modeled using mixed logistic regression models, including participants' study area as random effect, with incremental adjustment for confounders.

There were 315 cases of diabetes (prevalence: 5.5% [95% confidence interval (CI): 2.8, 7.2%]). Both PM_{10} and NO_2 were associated with prevalent diabetes with respective odds ratios of 1.40 [95% CI: 1.17, 1.67] and 1.19 [95% CI: 1.03, 1.38] per 10 $\mu g/m^3$ increase in the average home outdoor level. Associations with PM_{10} were generally stronger than with NO_2, even in the two-pollutant model. There was some indication that beta blockers mitigated the effect of PM_{10}. The associations remained stable across different sensitivity analyses.

Our study adds to the evidence that long term air pollution exposure is associated with diabetes mellitus. PM_{10} appears to be a useful marker of aspects of air pollution relevant for diabetes. This association can be observed at concentrations below air quality guidelines.

1. Introduction

Ambient air pollution, indoor air pollution and hyperglycemia constitute major risks for the global burden of disease (Lim et al., 2012). Air pollution is associated with cardiovascular diseases (Auchincloss et al., 2008; Hoffmann et al., 2007), and chronic respiratory diseases (Künzli et al., 2009; Schikowski et al., 2010) and has been shown to contribute to hospitalizations and deaths among cardiac disease patients (Goldberg et al., 2013), and diabetic patients (Goldberg et al., 2013; O'Neill et al., 2005; Zanobetti and Schwartz, 2001). Type 2 diabetes is increasing globally and is already one of the major causes of death (Lim et al., 2012). Type 2 diabetes and cardiovascular diseases share similar risk factors. Air pollution could be involved in the etiology of type 2 diabetes mellitus. Postulated mechanisms of action include oxidative stress and low grade inflammation, endothelial dysfunction, visceral adipose tissue inflammation, endoplasmic reticulum stress and mitochondrial dysfunction (Liu et al., 2013; Rajagopalan and Brook, 2012) with resulting impairment in insulin signaling (Xu et al., 2013).

Animal and human biomarker studies, including sparse epidemiological studies contribute to this evidence. Animal studies suggest a contribution of fine particles to insulin resistance, especially in association with a high fat diet (Sun et al., 2009; Xu et al., 2011; Yan et al., 2011). Chuang et al. (2007) demonstrated an alteration in glycosylated hemoglobin C, blood lipids and blood pressure in young adults in Taipei, after exposure to particulate matter and ozone.

Epidemiological evidence is sparse and findings are mixed. Longitudinal studies in European and North American populations (Andersen

* Corresponding author at: Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Socinstrasse 57, 4002 Basel, Switzerland. Tel.: +41 61 284 8378; fax: +41 61 284 8105.
E-mail address: Nicole.Probst@unibas.ch (N. Probst-Hensch).

http://dx.doi.org/10.1016/j.envint.2014.05.014

et al., 2012; Chen et al., 2013; Coogan et al., 2012; Krämer et al., 2010; Puett et al., 2011), found inconsistent associations between incident diabetes mellitus and PM_{10} [particulate matter < 10 μm in diameter], NO_2 [nitrogen dioxide], NO_x [nitrogen oxides], $PM_{2.5}$ [particulate matter < 2.5 μm in diameter], $PM_{10-2.5}$ [particulate matter with diameter between 2.5 and 10 μm] and residential proximity to traffic. Although the previous studies taken together with experimental evidence support the evidence for an association between inhaled pollutants and diabetes, several aspects may contribute to uncertainties and inconsistencies. Limiting factors toward more conclusive evidence include differences in (a) exposure metrics and assessment; (b) diabetes definition; (c) population characteristics and (d) covariates considered (Papazafiropoulou et al., 2011; Rajagopalan and Brook, 2012). Two epidemiological studies have investigated the association between air pollution and prevalent type 2 diabetes, with contradictory results on NO_2 effects (Brook et al., 2008; Dijkema et al., 2011). Noise can positively correlate with air pollution (Foraster, 2013; Kim et al., 2012) and has been implicated in cardiovascular diseases (Dratva et al., 2012; Sorensen et al., 2011), as well as more recently with diabetes (Sorensen et al., 2013). The quality and quantity of sleep have been shown to be significant predictors of the risk of type 2 diabetes (Cappuccio et al., 2010). Thus, noise can be considered a potential confounder in air pollution epidemiology studies.

To add to the epidemiologic evidence base on the newly uncovered, potentially causal relationship between air pollution and diabetes, we investigated the association between ambient/traffic-related air pollution and prevalent diabetes mellitus in the Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults [SAPALDIA], taking noise exposure, individual and area-level socio-economic index into consideration.

2. Materials and methods

2.1. Study population and health examinations

At baseline [SAPALDIA 1; 1991], the study population of SAPALDIA included 9561 randomly selected participants aged 18–65 years. These participants were selected from eight different areas in Switzerland, representing a wide range of environmental conditions in Switzerland. Subjects had extensive health examinations which involved computer-assisted interviews, lung function and allergy testing. At the first follow-up [SAPALDIA 2; 2002], the health assessments were repeated in 8047 participants, with more detailed interviews, including information on diabetes and other chronic non-communicable diseases, blood testing for biomarkers and genotyping. This is described in detail elsewhere (Ackermann-Liebrich et al., 2005). For the purpose of the present analysis, we had a sample of 6392 follow-up participants, aged 29–73 years, who had complete information on all the variables of interest, for assessing the association between air pollution and diabetes mellitus.

2.2. Definition of diabetes mellitus

At SAPALDIA 2, participants were asked “do you have diabetes mellitus?” and “was it diagnosed by a physician?” Participants' non-fasting blood samples were taken to measure blood markers, including non-fasting blood glucose, glycosylated hemoglobin C [HbA1c] and blood lipids. Based on the available information, we defined diabetes as present if at least one of the following conditions was met i) intake of any anti-diabetic medication; ii) self-reported, physician-diagnosed diabetes mellitus; iii) non-fasting blood glucose of >11.1 mmol/L or iv) HbA1c of >6.5% or 48 mmol/mol. Since this is an adult population [minimum age of 29 years] and >90% of diabetes in adults is of type 2, we assumed the majority of diabetic cases in this population to be type 2 diabetes mellitus.

2.3. Individual assignment of exposures

We considered markers of ambient air pollution [PM_{10}] and traffic-related air pollution [NO_2] as our air pollution exposure indicators. Estimates of mean ambient levels of these pollutants were available for the residential addresses of the participants in the years 1990 and 2000, the years before health assessments (Liu et al., 2007). They were obtained from validated dispersion models, with different emission inventories for both years. They have a spatial resolution of 200 × 200 m (Liu et al., 2007). Annual trends at fixed monitoring sites and participants' residential histories were used to estimate average ambient residential levels of the two pollutants over periods of 1 to 10 years prior to the first follow-up assessment in 2002. The dispersion model for PM_{10} provided good predictions both at background and traffic sites, whereas the model for NO_2 provided better predictions at traffic sites while underestimating levels at background sites (Liu et al., 2007). For this reason, the dispersion model for NO_2 was extended to a hybrid model involving land-use regression components (Liu et al., 2012). For this analysis, we primarily used the modeled average ambient levels of PM_{10} and NO_2 at participants' residential addresses over the 10 years preceding the first follow-up survey.

We obtained estimates of road traffic and railway noise from sonBASE, the Swiss national noise database (FOEN, 2009a,b). This database, developed by the Swiss Federal Office of Environment, provides average railway and road traffic noise estimates for day [0600 h–2200 h] and night [2200 h–0600 h]. Noise propagation was estimated with 10 × 10 meter grids and for individual buildings using the StL86 + emission model for road traffic noise and SEMIBEL [Swiss emission model for the estimation of railway noise] for railway noise (FOEN, 2009b). These estimates were then assigned to participants' residential addresses. From the day and night estimates, we estimated the average day–night [L_{dn}] noise exposure level by applying a penalty of 10 dB on the night noise estimates for both road traffic and railway noise. The L_{dn} value at the participant's address of the first follow-up survey was used as measure of individual noise exposure in the regression analysis.

2.4. Potential confounding variables

From the computer-assisted interviews at SAPALDIA 2, we extracted information on potential confounders. These included participants' age, sex [male, female], height and weight to compute the body mass index [BMI; kg/m^2], and educational attainment [low corresponding to primary education; intermediate corresponding to secondary, middle, or vocational school; and high corresponding to technical college or university]. Neighborhood-level socio-economic index was obtained for participants' residential areas. This index was defined using neighborhood characterization based on median rent, occupation and education of heads of households and crowding of households, combined in a principal component analysis (Panczak et al., 2012). We also extracted information on physical activity [≤0.5 h per week, 0.5–2 h per week and >2 h per week of vigorous activity], smoking [never, former, current and pack years smoked], environmental tobacco smoking in the past 12 months [never smoker, and former smoker] and alcohol consumption [never, ≤once a day, and >once a day], and occupational exposure to gases, dusts and fumes [yes/no]. In addition, we extracted information on consumption of raw vegetables [never, ≤3 days per week, and >3 days per week], consumption of citrus fruits [never, ≤3 days per week, and >3 days per week] and consumption of other fruits [never, ≤3 days per week, and >3 days per week]. We also extracted information on some existing co-morbidities including hypertension [yes/no], and chronic obstructive pulmonary disease [COPD; defined by GOLD standard: forced expiratory volume in 1 s (FEV_1) ÷ forced vital capacity (FVC) < 0.7; yes/no].

Since the parameter of air pollution exposure was the mean ambient residential level over the ten years preceding the first follow-up survey, we also considered some baseline exposure characteristics, as potential