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Long-term exposure to residential railway and road traffic noise and risk for diabetes in a Danish cohort

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ABSTRACT

Background: Road traffic noise exposure has been found associated with diabetes incidence. Evidence for an association between railway noise exposure is less clear, as large studies with detailed railway noise modelling are lacking.

Purpose: To investigate the association between residential railway noise and diabetes incidence, and to repeat previous analyses on road traffic noise and diabetes with longer follow-up time.

Methods: Among 50,534 middle-aged Danes enrolled into the Diet, Cancer and Health cohort from 1993 to 97, we identified 5062 cases of incident diabetes during a median follow-up of 15.5 years. Present and historical residential addresses from 1987 to 2012 were found in national registries, and railway and road traffic noise (L_{den}) were modelled for all addresses, using the Nordic prediction method. We used Cox proportional hazard models to investigate the association between residential traffic noise over 1 and 5 years before diagnosis, and diabetes incidence. Hazard ratios (HRs) were calculated as crude and adjusted for potential confounders.

Results: We found no association between railway noise exposure and diabetes incidence among the 9527 persons exposed, regardless of exposure time-window: HR 0.99 (0.94–1.04) per 10 dB for 5-year exposure in fully adjusted models. There was no effect modification by sex, road traffic noise, and education. We confirmed the previously found association between road traffic noise exposure and diabetes including 6 additional years of follow-up: HR 1.08 (1.04–1.13) per 10 dB for 5-year exposure in fully adjusted models.

Conclusion: The study does not suggest an association between residential railway noise exposure and diabetes incidence, but supports the finding of a direct association with residential road traffic noise.

1. Introduction

Traffic noise is among the most important environmental risk factors affecting public health in Europe, as a result of its ubiquitous nature in modern-day urbanized societies (Hanninen et al., 2014). It has consistently been found related to an increased risk of cardiovascular disease (Vienneau et al., 2015; Munzel et al., 2016), and the WHO estimates that at least one million disability-adjusted life-years are lost yearly in Western Europe as a result of environmental noise (World Health Organization, 2011).

Two recent studies proposed also an association between residential road traffic noise and diabetes (Sorensen et al., 2013; Eze et al., 2017). Potential explanations for this include that traffic noise entails sleep disruption (World Health Organization, 2009; Pirrera et al., 2010; Miedema and Vos, 2007), which is increasingly recognized to affect metabolic functioning negatively, through a range of pathways, including disturbing the circadian rhythm, disrupting glucose metabolism, affecting appetite regulation, and lowering energy expenditure, as reviewed in (McHill and Wright, 2017). In accordance with this, studies have found an association between traffic noise exposure and obesity and metabolic markers (Christensen et al., 2015, 2016; Pyko et al., 2015; Eriksson et al., 2014). Furthermore, noise functions as an environmental stressor, entailing activation of the hypothalamic-pituitary-adrenocortical axis, resulting in several metabolic responses, including overproduction of cortisol and insulin resistance, as reviewed in (Recio et al., 2016). Finally, residential traffic noise have been proposed associated with physical inactivity (Foraster et al., 2016; Roswall et al., 2017), a known risk-factor for diabetes (Forouhi and Wareham, 2014). Taken together, this suggests a role for traffic noise in diabetes etiology.

Railway noise is another frequent noise source, with approximately

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19 million Europeans exposed above 55 dB (European Environment Agency, 2017). Railway noise is generally considered as less annoying than both road traffic and aircraft noise (Miedema and Vos, 1998). Two previous studies have investigated associations between railway noise and diabetes: A recent study with 2631 participants, of which only few were exposed to railway noise, found no association with diabetes (Eze et al., 2017). Also, we previously found no association between railway noise and diabetes in a cohort of 57,053 participants, but our previous estimate of railway noise was very crude (above vs. below 60 dB), and did not include noise screening by buildings or noise screens (Sorensen et al., 2013).

Hence, the present study aimed to investigate the association between residential railway noise and diabetes incidence, based on an updated and significantly improved modelling of railway noise exposure, in a prospective, Danish cohort. Furthermore, we investigated effect modification by sex, road traffic noise and education. Finally, we re-analyzed the association between road traffic noise and diabetes in the cohort over an increased follow-up period.

2. Material and methods

2.1. Study population

A detailed description of the Diet, Cancer and Health cohort is published previously (Tjonneland et al., 2007). Briefly; 160,725 Danes were invited to participate from 1993 to 97. Inclusion criteria were residence in the greater Copenhagen or Aarhus area, 50–64 years of age, and no previous cancer diagnosis in the Danish Cancer Registry. In total, 57,053 participants (29,875 women) accepted, and were included into the study, representing 7% of the Danish population in this age-group. The study was approved by the local ethical committees of Copenhagen and Frederiksberg Municipalities. All participants provided written informed consent, and the study was conducted according to the Helsinki Declaration.

2.2. Traffic noise assessment

Residential address history was collected for all participants between July 1st, 1987 and February 10th, 2012, using the Danish civil registration system (Pedersen, 2011). Railway and road traffic noise exposure was calculated at the most exposed façade and at dwelling height, using SoundPLAN, implementing the joint Nordic prediction method for road traffic noise (Bendtsen, 1999). Using this method, equivalent noise levels can be calculated for each address, when a series of traffic and topographic parameters are known.

The input variables for railway noise estimation were receptor points (geographical coordinate and height (floor)), railway links with information on annual average daily train lengths, train types, travel speed (obtained from Banedanmark, which is operating and developing the Danish state railway network), and building polygons (3D) for all Danish buildings, including noise screening from buildings. The daily train lengths are given for 1997 and 2011. All noise barriers along the railway were also included in the model.

Input variables for road traffic noise estimation were receptor points (geographical coordinates and height (floor) for each residential address), and building polygons for all Danish buildings, as well as traffic information on road links (information on annual average daily traffic, vehicle distribution (light/heavy), travel speed, and road type) as described in details previously (Sorensen et al., 2013). Information on noise barriers along the road was not available.

Traffic noise was calculated as the equivalent continuous A-weighted sound pressure level (L_{Aeq}) at the most exposed facade of the dwelling at each address for the day (L_d; 07:00–19:00 h), evening (L_e; 19:00–22:00 h) and night (L_n; 22:00–07:00 h), and expressed as L_{den} (den = day, evening, night). A 5 and 10 dB penalty was applied to evening and night, respectively (European Comission, 2002).

We assumed that the terrain was flat, which is a reasonable assumption in Denmark, and that urban areas, roads, and areas with water were hard surfaces, whereas all other areas were acoustically porous.

Exposure to railway and road traffic noise was modelled as time-weighted averages for periods of 1 and 5 years preceding diabetes diagnosis (taking all present and historical addresses in that period into account), and in a sensitivity-analysis also over 10 years for those with 10 years or more of follow-up. Railway noise was operationalized both as a continuous variable (per 10 dB), and as a categorical variable in the following categories (quintiles): ≤ 20 dB, > 20–43.2 dB, > 43.2–49.8 dB, > 49.8–56.6 dB, > 56.6 dB, based on the distribution of railway traffic noise exposure among cases. For road traffic noise, values below 40 dB were set to 40 dB as this was considered a realistic lower limit of ambient noise. For railway noise, persons with an exposure below 20 dB were considered non-exposed.

In a previous study, we examined railway noise exposure and diabetes incidence in the same cohort using a very crude modelling which calculated exposure in range 60–80 dB and did not include noise screens or buildings. Details on this previous model can be found in (Sorensen et al., 2013).

2.3. Identification of cases

Diabetes cases diagnosed between baseline and death, emigration or end of follow-up, were identified by linkage to the Danish National Diabetes Registry (NDR) (Carstensen et al., 2008). Inclusion criteria for the NDR were: a hospital discharge diagnosis of diabetes in the National Patient Register (*International Classification of Diseases, 10th Revision* [ICD-10; World Health Organization (WHO) 1993]: DE10–14, DH36.0 and DO24); National Health Insurance Registry information indicating podiatry (chiropody) for diabetic patients, > 1 purchase of insulin or oral glucose-lowering drugs within 6 months registered in the Register of Medicinal Product Statistics, five blood glucose measurements within 1 year, or two blood glucose measurements per year for 5 consecutive years. The registry has been reported to have a positive predictive value of 89% (Carstensen et al., 2011). We applied a strict diabetes definition, by excluding individuals registered in the NDR solely because of a history of blood glucose tests, as suggested in a validation study (Green et al., 2015). Among the 5062 cases included in our study, 67% met more than one of the strict inclusion criteria. The date of inclusion into the NDR has been found well-defined only for persons entering after January 1st, 1995 (Carstensen et al., 2008), so the incidence of diabetes is defined as the date of the earliest record in the NDR after January 1st, 1995 and before February 10th, 2012. Participants were excluded from the study if they were diagnosed with diabetes before 1995 or baseline (if enrolled after 1995).

2.4. Covariates

The selection of covariates was done *a priori,* based on a review of existing literature, biological plausibility, and availability of data.

As road traffic is a primary source of both air pollution and noise in urban environments (Allen and Adar, 2011), we calculated NO_x exposure in the cohort using the Danish AirGIS dispersion modelling system based on modelled street concentrations (http://envs.au.dk/en/knowledge/air/models/airgis/) for the same years as exposure to traffic noise, for all addresses where each individual had lived, as previously described in detail (Sorensen et al., 2013).

At enrolment, all participants completed self-administered, interviewer-checked, food frequency (fruit and vegetable intake) and lifestyle questionnaires, covering education, and lifestyle habits (smoking, alcohol, and physical activity). Height, weight, and waist circumference were measured according to standardized protocols by trained staff members at enrolment. This is all described in detail in (Tjonneland et al., 2007). Area-level socioeconomic status at enrolment was