Environmental Research xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Environmental Research

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

Road traffic noise, blood pressure and heart rate: Pooled analyses of harmonized data from 88,336 participants

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ARTICLE INFO

Keywords:
Blood pressure
Heart rate
Noise
Air pollution
Epidemiology
Meta-analysis

ABSTRACT

Introduction: Exposure to road traffic noise may increase blood pressure and heart rate. It is unclear to what extent exposure to air pollution may influence this relationship. We investigated associations between noise, blood pressure and heart rate, with harmonized data from three European cohorts, while taking into account exposure to air pollution.
Methods: Road traffic noise exposure was assessed using a European noise model based on the Common Noise Assessment Methods in Europe framework (CNOSSOS-EU). Exposure to air pollution was estimated using a European-wide land use regression model. Blood pressure and heart rate were obtained by trained clinical professionals. Pooled cross-sectional analyses of harmonized data were conducted at the individual level and with random-effects meta-analyses.
Results: We analyzed data from 88,336 participants, across the three participating cohorts (mean age 47.0 (± 13.9) years). Each 10 dB(A) increase in noise was associated with a 0.93 (95% CI 0.76;1.11) bpm increase in heart rate, but with a decrease in blood pressure of 0.01 (95% CI −0.24;0.23) mmHg for systolic and 0.38 (95% CI −0.53; −0.24) mmHg for diastolic blood pressure. Adjustments for PM_{10} or NO_2 attenuated the associations, but remained significant for DBP and HR. Results for BP differed by cohort, with negative associations with noise in LifeLines, no significant associations in EPIC-Oxford, and positive associations with noise > 60 dB(A) in HUNT3.
Conclusions: Our study suggests that road traffic noise may be related to increased heart rate. No consistent evidence for a relation between noise and blood pressure was found.

1. Introduction

Traffic-related noise poses a significant risk to human health (WHO, 2011). Higher noise exposure has been associated with increased risks for cardiovascular disease (Fecht et al., 2016; Halonen et al., 2015). Noise is generally believed to provoke stress

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http://dx.doi.org/10.1016/j.envres.2016.09.014
Received 22 March 2016; Received in revised form 6 September 2016; Accepted 16 September 2016
Available online xxxx
0013-9351/

through perceived discomfort (Bluhm et al., 2004), and also to result in subconscious activation of stress systems (Recio et al., 2016). Direct or indirect activation of the sympathetic and endocrine systems is followed by increases in heart rate, blood pressure, and release of stress hormones (Chrousos and Gold, 1992). Noise-induce sleep disturbance may also disrupt secretion of stress hormones, affecting metabolism and the cardiovascular system, ultimately resulting in cardiovascular disease (Münzel et al., 2014).

Some studies have found associations between traffic noise and hypertension (Foraster et al., 2014; van Kempen and Babisch, 2012) but in other studies the relation was less clear (Babisch et al., 2014; Sorensen et al., 2011), or only observed in specific subgroups (e.g. diabetes patients) (Dratva et al., 2012). These inconsistencies may due to differences in the assessments of noise exposure, covariates, blood pressure or differences across statistical approaches used (van Kempen and Babisch, 2012).

The role of air pollution in the relation between traffic noise and hypertension is unclear. Exposure to ambient air pollution is also associated with hypertension (Cai et al., 2016) and cardiovascular morbidity and mortality (Brook et al., 2010). As road traffic is the main common source for both noise and air pollution, it is important to distinguish the cardiovascular effects of each. Until recently, studies did not take into account exposures to traffic-related noise and air pollution simultaneously. A systematic review based on nine studies up to 2012 suggested a likely independent effect of both traffic-related noise and air pollution on cardiovascular disease (Tétreault et al., 2013), which was further supported by a recent updated review (Stansfeld, 2015) However, as only a handful of studies were available, a definitive conclusion on the respective roles of air pollution and noise on cardiovascular disease cannot yet be drawn, and this issue warrants further research.

Compared to blood pressure studies, there are far fewer studies investigating the association with heart rate in adults to date (Holand et al., 1999; Raggam et al., 2007),

The aim of this cross-sectional study was to investigate associations between road traffic noise, blood pressure and heart rate, while taking into account exposure to ambient air pollution. We investigated these associations in 88,336 adults from three European cohorts: LifeLines, EPIC-Oxford and HUNT3. We used a harmonized approach and federated data analyzes to enable comparisons of results between different studies and regions.

2. Methods

2.1. Study populations

This study was undertaken within the Biobank Standardisation and Harmonization for Research Excellence in the European Union (BioSHaRE-EU) project, using a harmonized approach to noise and air pollution exposure, health data and potential confounders. Within BioSHaRE, tools were developed for data harmonization and federated data analyses (Doiron et al., 2013). Data were obtained from three European cohorts: LifeLines (the Netherlands) (Scholtens et al., 2014; Zijlema et al., 2016), EPIC-Oxford (United Kingdom) (Davey et al., 2003), and HUNT3 (Norway) (Krokstad et al., 2013). LifeLines is a multi-disciplinary prospective population based cohort study examining the health and health-related behaviors of persons living in the North East region of the Netherlands. Recruitment occurred through general practitioners, online self-registration, and subsequent inclusion of participants' family members. EPIC-Oxford (the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition) is a nationwide study in the UK aimed at investigating how diet influences the risk for cancers and other chronic diseases. Participants were recruited via general practice and postal recruitment. In addition to inclusion of members of the general population, recruitment was focused on including participants with a wide range of dietary habits as well as vegetarians and vegans. HUNT3 (the 3rd survey of the Nord-Trøndelag Health Study) is a prospective population based study from the Nord-Trøndelag County in Norway, examining health related lifestyle, prevalence and incidence of somatic and mental illness and disease, health determinants, and associations between disease phenotypes and genotypes. Recruitment occurred through national census data. All individual participants provided written informed consent and study protocols were approved by the local ethical committees.

The present study included baseline data with road traffic noise and air pollution estimates available for 156,424 participants, aged between 18 and 92 years. Participants with incomplete data regarding blood pressure and heart rate measurements (n=33,059; mainly because in EPIC-Oxford these parameters were only measured in a subsample), educational level (n=19,052, mainly because this data was lacking in HUNT3 and was used from HUNT2, see covariates paragraph), BMI (n=146), and alcohol use and smoking status (n=15,831) were excluded. Participants with incomplete data regarding antihypertensive medication use (n=2) were excluded from the corresponding analyses.

2.2. Road traffic noise exposure assessment

Exposure to road traffic noise was assessed at individual home addresses using the Common Noise Assessment Methods in Europe (CNOSSOS-EU) noise model (Kephalopoulos et al., 2014). The CNOSSOS-EU framework contains empirically derived equations to determine average noise level based on traffic flow, and sound propagation based on known environmental factors and physical processes. Quantitative data of road networks, traffic flows, land cover, building height, and meteorology were obtained from local sources. Propagation effects such as distance from receiver to the noise source, land cover type, building obstruction, and meteorological conditions are included as sound propagation parameters in the model. Traffic data originated from year 2009 and land cover data from 2006. Detailed land cover data at the scale of our study regions were not available to allow positioning of the receptor at the most exposed façade. Therefore a coarser land cover data set was used to approximate urban fabric. A fixed baseline traffic flow was assigned to participants living on minor roads that were not captured in the national level traffic datasets. Some lower resolution data inputs were used within the CNOSSOS-EU noise model to obtain comparable exposure estimates across the wide regions in our study. Model validation showed adequate performance for exposure ranking: discrimination between noisier and quieter areas gave Spearman's rank=0.75; $p < 0.001$. The lower resolution data derived model has however relatively large errors in the predicted noise levels (root mean square error (RMSE)=4.46 dB(A)) (Morley et al., 2015). The noise metric L_{den} (day-evening-night time period of 24 h) is used. L_{den} is the average A-weighted noise level, estimated over a 24 h period, with a 10 dB penalty added to the night (23.00–07.00 h), and a 5 dB penalty added to the evening period (19.00–23.00 h), to indicate people's extra sensitivity to noise during the night and evening.

2.3. Ambient air pollution exposure assessment

Exposure to particulate matter with a diameter ≤10 μm (PM_{10}) and nitrogen dioxide (NO_2) at individual home addresses was estimated using a land use regression (LUR) model for Western Europe on a resolution of $100\times100\ m^2$ (Vienneau et al., 2013). Geographical Information System-derived land use, topographic data, and satellite-derived estimates of ground-level concentration of $PM_{2.5}$ (as an indicator of PM_{10}) and NO_2 were used to predict the dependent variables ambient concentrations of PM_{10} and NO_2 obtained from regulatory monitoring (EuroAirnet, years 2005–2007). Models were evaluated against measured PM_{10} and NO_2 concentrations at an independent subset of measurement sites. LUR models explained 55–60% (NO_2) and 38–47% (PM_{10}) of the variation in measured