Environmental Research 133 (2014) 380–387

Contents lists available at ScienceDirect

Environmental Research

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

Road traffic noise and hypertension – Accounting for the location of rooms

Wolfgang Babisch [a,*], Gabriele Wolke [b], Joachim Heinrich [b], Wolfgang Straff [a]

[a] Department of Environmental Hygiene, Federal Environment Agency, Corrensplatz 1, 14195 Berlin, Germany
[b] Institute of Epidemiology I, Helmholtz Zentrum München, Ingolstädter Landstraße 1, 85764 Neuherberg, Germany

ARTICLE INFO

Article history:
Received 19 March 2014
Received in revised form
17 April 2014
Accepted 6 May 2014
Available online 18 June 2014

Keywords:
Road traffic noise
Hypertension
Length of residence
Room orientation
Daytime versus night-time
Living room versus bedroom

ABSTRACT

Objective: The association between the exposure to road traffic noise and the prevalence of hypertension was assessed accounting for background air pollution and the location of rooms with respect to the road.
Methods: A cross-sectional study was carried out inviting all subjects aged 35–74 years for participation that lived on 7 major trunk roads in 3–4 storey terraced apartment buildings and in parallel side streets that were completely shielded from noise due to the rows of houses along the major roads. The study was performed on 1770 subjects that did not have a self-reported medical doctor diagnosis of hypertension before they moved into their current residence. Noise levels at the facade of the front and the rear side of the houses were drawn from available noise maps of the area. A large set of covariates were considered to adjust the results for confounding.
Results: Significant increases between road traffic noise and hypertension were found with respect to the 24 h A-weighted average noise indicator L_{DEN}. The adjusted odds ratio (OR) per noise level increment of 10 dB(A) was 1.11 (95% confidence interval (CI): 1.00–1.23). Stronger significant estimates of the noise effect were found in subjects with long residence time (OR=1.20, CI=1.05–1.37), and with respect to the exposure of the living room during daytime (OR=1.24, CI=1.08–1.41) compared with the exposure of the bedroom during night-time (OR=0.91, CI=0.78–1.06).
Conclusion: Chronic exposure to road traffic noise is associated with an increased risk of high blood pressure. Daytime noise exposure of the living room had a stronger impact on the association than night-time exposure of the bedroom.

1. Introduction

Transportation noise has been considered as a risk factor for serious annoyance, sleep disturbance, cognitive impairment, physiological stress reactions, endocrine imbalance, and cardiovascular disorders (Basner et al., 2014; van Kamp et al., 2012; Münzel et al., 2014). The cardiovascular effects - including high blood pressure, ischaemic heart diseases and stroke – have deserved growing interest in recent years. The general stress theory is the rationale for the hypothesis that noise affects the autonomic nervous system and the endocrine system, which in turn affects the homoeostasis of the human organism (Henry, 1992; McEwen, 1998). The evidence has increased that noise affects cardiovascular health (EEA, 2010; WHO Regional Office for Europe, 2011). The state of research has been condensed in review articles (Belojevic et al., 2011; Bluhm and Eriksson, 2011; Davies and Van Kamp, 2012; van Kempen, 2011; Lercher et al., 2011; Maschke, 2011; Ndrepepa and Twardella, 2011; Paunovic et al., 2011; Stansfeld and Crombie, 2011; Swift, 2010). Meta-analyses have been carried out showing exposure-response relationships between road traffic and aircraft noise – on the one hand – and the prevalence and incidence of cardiovascular diseases on the other (Babisch, 2008, 2014; Babisch and van Kamp, 2009; van Kempen and Babisch, 2012).

With respect to the relationship between road traffic noise and high blood pressure only a few studies had taken background air pollution (particulate matter or nitrous gases) into account as a potential confounding factor of the associations (Dratva et al., 2012; Fuks et al., 2011; de Kluizenaar et al., 2007; Sørensen et al., 2011). However, the effects of noise and air pollution seem to be largely independent of one another (Lekaviciute et al., 2012; Tétreault et al., 2013). This may be due to differences in the spatial

Abbreviations: CI, confidence interval; dB(A), decibel (A); L_{DEN}, weighted day-evening-night average noise indicator over 24 h; L_{Day}, day-time average noise indicator over 16 h L_{Night}, night-time average noise indicator over 8 h; N, number of subjects; NO_2, nitrous dioxide; OR, odds ratio; PM_{10}, mass concentrations of particles less than 10 μm in size; $PM_{2.5}$, mass concentrations of particles less than 2.5 μm in size; P-value, error probability; r_p, correlation coefficient; RR, relative risk; SD, standard deviation

* Corresponding author. Tel.: +49 30 8903 1370; fax: +49 340 2104 1370.
E-mail address: wolfgang.babisch@t-online.de (W. Babisch).

http://dx.doi.org/10.1016/j.envres.2014.05.007
0013-9351/

resolution of the exposure assessment, but also due to the different biological mechanisms of how the exposure could affect blood pressure – cognitive and autonomic stress response vs. inflammatory processes (Babisch, 2002; Brook et al., 2004; Brook and Rajagoplan, 2009).

Road traffic noise is a major source of noise in the urban environment (WHO Regional Office for Europe, 2011). Hypertension is one of the leading risk factors for premature death and disability from heart disease, stroke, peripheral vascular disease, and kidney failure in the world (Kearney et al., 2005; Ward et al., 2012; WHO, 2011). In order to assess the relationship between the exposure to road traffic noise and high blood pressure we assessed road traffic noise and the prevalence of hypertension in a community sample. To account for background air pollution we considered a novel approach. Rather than drawing a random sample from the whole city of Berlin we concentrated on a small scale area with busy roads and quiet side streets where all inhabitants were invited to participate in the study. Furthermore, we were able to distinguish between the exposure of the living room and the bedroom taking into account the location of the rooms with respect to the road and the noise attenuation due to the shielding of the houses. To our knowledge, this has never been done before in previous noise studies. However, it is of importance for noise mitigation measures and related public health policies.

2. Methods

2.1. Sample selection

We carried out a cross-sectional study in the city of Berlin. Other than in most other studies where a random sample of subjects is drawn from all over the area, we restricted our study area to 7 major road arteries that were located in 2 local districts of Berlin. All subjects aged 35–74 years that lived in 2009 on these roads and in first or second row parallel side streets with insignificant traffic volume were invited to participate in our study. The names and addresses were provided from the central residential registry office of Berlin. The field work was carried out in 2010 and 2011. The roads were characterised by blocks of 3 to 4-storey high rows of terraced apartment buildings providing complete shielding from the traffic noise of rooms on the rear side of the buildings and of other houses further away from the road. However, there were a few exceptions where buildings were standing crosswise to the road and where the front and the back side were equally exposed. In agreement with restrictions from the data protection commissioner, the following procedure of recruiting the subjects was applied. Firstly, an invitation letter was sent to all subjects of the source population. Secondly, if the subjects did not respond within 2–3 weeks a reminder letter was sent. Thirdly, if again there was no response we tried to contact the subjects by telephone taking up to three attempts at different times of the day, including the evening. Unfortunately, only approximately 20% of the candidates were listed in telephone directories, which is due to the rapid use of mobile phones. Fourthly, for subjects that could not be contacted by phone, at least one attempt was undertaken to recruit them at the doorstep ("knocking doors").

All study participants were visited at home for blood pressure measurements and a 1-hour face-to-face interview. The study was approved by the ethical committee of the medical association of Berlin and the data protection commissioner of the city of Berlin.

2.2. Hypertension

The blood pressure measurements were carried out using a validated automatic oszillometric device (Omron Type M5-I), which has been used in other studies (Jarup et al., 2008). Such instruments are well established in clinical research and are used in occupartional and environmental medicine (Staessen et al., 2000). We followed exactly the protocol of the HYENA study (Jarup et al., 2008). Specially trained staff assessed the blood pressure three times during home visits. The first measurement was recorded at the beginning of the interview after a 5 minute rest period. The second measurement was recorded after a further minute rest in accordance with recommedations of the American Heart Association (Pickering et al., 2005). The third blood pressure reading was taken at the end of the interview as a validity control. The second blood pressure measurement was taken for subsequent analyses because it showed the lowest values (best foundation of baseline blood pressure). Using the mean of all three measurements did not change the results. All blood pressure measurements were performed with the participant in a sitting position. Home visits were distributed over the whole day as far as feasible, to account for diurnal variations.

Systolic/diastolic blood pressure readings $\geq 140/90$ mmHg were classified as hypertensive according to guidelines (WHO and ISH, 2003). During the interview the participants were asked whether – and if yes, when – a doctor had ever diagnosed high blood pressure and whether they take anti-hypertensive medication. The subjects had to show all the medication that they regularly took. Based on the substances and ATC coding (anatomical therapeutic chemical classification system) antihypertensive treatment was verified. If the subjects took medication that was anti-hypertensive (as an unknown side effect) but had not reported being doctor diagnosed for hypertension, they were not classified as such. Participants were classified as having prevalent hypertension based on self-reported doctor diagnosed hypertension or measured blood pressure $\geq 140/90$ mmHg or use of anti-hypertensive medication in conjunction with self-reported doctor diagnosed hypertension, as in previous studies (Babisch et al., 2014; Jarup et al., 2008)). In accordance with the study objective we excluded subjects from our main analyses that had their first doctor-diagnosis of high blood pressure before they moved to their current home (of which we assessed the noise exposure).

2.3. Noise

The assessment of traffic noise is based on the strategic noise map made available by the City of Berlin (FIS Broker, 2013; Berlin Noise Map, 2013). The noise map is based on the 2011 update of 2007 input data. The noise level calculations were carried out according to the German calculation method VBUS in accordance to the European Environmental Noise Directive (Directive 2002/49/EC, 2002; VBUS, 2006). Input data for the calculation of noise levels were: traffic volume, percentage of heavy vehicles, speed limit, road surface, road gradient, air absorption and reflections, taking into account the terrain and obstructions from objects. The noise propagation modelling was made with respect to immission points 4 m above the ground at the facade of the buildings. The noise map provided estimates of the annual A-weighted energy-equivalent average noise indicators L_{DEN} and L_{Night} of all sides of the houses. L_{DEN} is a 24 h average noise level where penalties of +5 and +10 dB(A) are given to the evening period (18–22 h) and the night period (22–06 h), respectively (Directive 2002/49/EC, 2002). The highest noise level at any facade has been considered as a noise indicator in previous noise studies, because more detailed information was not available. Our main analyses refer also to the most exposed facade.

During the clinical interview the subject marked the orientation of the living room and the bedroom with respect to the road (postal address) on a diagram (windows facing the front, left or right, or rear side). In the case that a room had windows facing the street on more than one side, we considered the noisiest side for the exposure side (e.g. front side nosier than left or right side). Since we could assess noise levels at the front of the houses and on the rear side, we were able to carry out separate analyses with respect to the exposure of the living room during daytime and the bedroom during night-time, taking into account the location of the rooms. The noise indicator L_{Day} during daytime (06–22 h) was calculated from L_{DEN} and L_{Night} (Directive 2002/49/EC, 2002).

2.4. Air pollution

The assessment of background air pollution, nitrous dioxide (NO_2) and particulate matter (mass concentrations of particles less than 10 μm (PM_{10}) and less than 2.5 μm ($PM_{2.5}$) in size) was based on the BLUME air pollution monitoring network of Berlin (BLUME, 2013). It consists of 16 stations of which 5 stations were relevant for the study area. For the assessment of the background concentrations of the air pollutants in the participants living areas the measured concentration of the 2005 and 2008 were interpolated, taking into account the long-term distribution of wind directions. Since the study area in the south–west of Berlin was small only minor differences between the 2 local districts from where we had chosen our roads were to be expected. Furthermore, busy streets and adjacent quiet streets were within approximately 200 m distance from one another, separated by long sound isolating rows of terraced houses. All three air pollution indicators were highly correlated ($r_p > 0.89$). Only $PM_{2.5}$ was considered in the final models because it is the biologically most relevant candidate with respect to cardiovascular diseases (Brook and Rajagoplan, 2009; Linares et al., 2009).

2.5. Covariates

To adjust for potential confounding we assessed the following factors that were assessed by questionnaire during the home visit: age (years), gender (men, women), smoking (never smoker, former smoker, ≤ 10 cigarettes or ≤ 1 cigar or pipe per day, > 10 cigarettes or > 1 cigar or pipe per day), alcohol consumption (units of 0.2 l wine or 0.3 l beer or 0.2 cl spirits per week), salt intake (always adding salt to meals, other), fruit/vegetable intake (meals per week), physical activity (never, not regularly, moderately 1–3 times, moderately > 3 times, strenuous 1–3 times, strenuous > 3 times per week), education (highest level based on school education and professional training according to Helmert and Shea