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Individual daytime noise exposure in different microenvironments

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ABSTRACT

Background: Numerous studies showed that chronic noise exposure modeled through noise mapping is associated with adverse health effects. However, knowledge about real individual noise exposure, emitted by several sources, is limited.
Objectives: To explain the variation in individual daytime noise exposure regarding different microenvironments, activities and individual characteristics.
Materials and methods: In a repeated measures study in Augsburg, Germany (March 2007–December 2008), 109 individuals participated in 305 individual noise measurements with a mean duration of 5.5 h. Whereabouts and activities were recorded in a diary. One-minute averages of A-weighted equivalent continuous sound pressure levels (L_{eq}) were determined. We used mixed additive models to elucidate the variation of L_{eq} by diary-based information, baseline characteristics and time-invariant variables like long-term noise exposure.
Results: Overall noise levels were highly variable (median: 64 dB(A); range: 37–105 dB(A)). Highest noise levels were measured in traffic during bicycling (69 dB(A); 49–97 dB(A)) and lowest while resting at home (54 dB(A); 37–94 dB(A)). Nearly all diary-based information as well as physical activity, sex and age-group had significant influences on individual noise. In an additional analysis restricted to times spent at the residences, long-term noise exposure did not improve the model fit.
Conclusions: Individual exposures to day-time noise were moderate to high and showed high variations in different microenvironments except when being in traffic. Individual noise levels were greatly determined by personal activities but also seemed to depend on environmental noise levels.

1. Introduction

A growing body of evidence shows adverse associations between chronic noise exposure and human health. Several epidemiological studies have identified noise exposure to be a major contributor to hearing loss (Sliwinska-Kowalska and Davis, 2012), sleep disturbance (Hume et al., 2012), cardiovascular disease (Davies and Kamp, 2012), impairment of performance (Clark and Sorqvist, 2012), altered endocrine responses (Babisch, 2003), mental illness as well as annoyance (Stansfeld and Matheson, 2003). Most of these associations were assessed in long-term studies, where noise was predicted through strategic noise mapping. Thereby, these studies concentrated on noise exposure from selected sources, in particular road traffic, railway system, aircraft and occupational settings. The results of these studies provided the basis for the development of guideline values (Berglund et al., 1999; WHO, 2009) and the calculation of burden of disease in terms of disability-adjusted life-years (WHO, 2011, 2012). As a consequence, traffic noise was placed as the second most dangerous environmental threat to human health after air pollution in six European countries (EBoDE, 2010; Hanninen et al., 2014). However, people are usually exposed to noise from more than one source simultaneously. Also, noise levels predicted through noise mapping do not provide valid information about individual exposure. To date, only a few studies measured noise continuously and were able to describe noise levels in specific microenvironments or during different activities (Boogaard et al., 2009; Clark, 1991; Diaz and Pedrero, 2006; Flamme et al., 2012; Neitzel et al., 2004b; Neitzel et al., 2014; Weinmann et al., 2012; Zheng et al.,

Abbreviations: CI, confidence interval; dB(A), A-weighted decibels; KORA, Cooperative Health Research in the Region of Augsburg; L_{day}, Maximum annual A-weighted equivalent continuous sound pressure levels during the day (6 am to 6 pm); L_{eq}, A-weighted equivalent continuous sound pressure levels; LOD, limit of detection; PNC, particle number concentration; R^2, coefficient of determination; sd, standard deviation; VIF, variance inflation factor; WHO, World Health Organization

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1996). Most of these studies concluded that 24- hour means of individual noise exposure was high with levels exceeding the recommended limit of 70 dB(A) for prevention of hearing loss (Berglund et al., 1999). However, these 24-h means depended on very specific activities contributing the majority of the total noise dose but accounting only for a minority of the individual's total investigated time (Diaz and Pedrero, 2006; Neitzel et al., 2004b). Still, knowledge on individual noise levels in typical situations of daily life remains limited.

In Augsburg, Germany, an epidemiological study was conducted to assess the health effects of different environmental stressors on cardiovascular health (Hampel et al., 2012; Kraus et al., 2013; Schauble et al., 2012). Within this study, personal measurements of noise were performed. In a former analysis, we observed that individual noise was associated with adverse changes in heart rate variability, with higher effects at lower noise levels (Kraus et al., 2013). The objective of the present analysis was (i) to describe individual daytime noise exposure in different typical microenvironmental settings and (ii) to evaluate which factors are useful determinants of individual noise exposure in adults during daytime by the use of multiple regression models.

2. Materials and methods

2.1. Study design

As part of the Rochester Particulate Matter Center investigations, an epidemiological study was conducted in Augsburg and two adjacent rural districts Augsburg and Aichach-Friedberg, Germany, between March 19th 2007 and December 17th 2008. Augsburg is located in the south-west of Bavaria and covers 147 km^2. It is the third-largest city in Bavaria with a population exceeding 260,000 citizens. The two districts cover 1851 km^2 and have a population of more than 368,000 citizens (Bavarian state office for statistics and data processing, as per 31.12.2008). Augsburg Airport is located seven kilometers from Augsburg's city center in north-easterly direction. Participants were recruited from the follow-up examination of the KORA (Cooperative Health Research in the Region of Augsburg) survey 2000 (Holle et al., 2005) conducted in 2006–2008. They were invited to participate in up to four personal exposure measurements scheduled every four to six weeks on the same weekday between 7:30 am and 3 pm. In this period, participants were free to pursue their daily routines. For further information on the recruitment see Supplemental material.

2.2. Activity diary

The participants were instructed to enter their activities and whereabouts and changes of these in a diary. For information on whereabouts, participants could tick whether they were indoors, outside but not in traffic (e.g. in a park), or in traffic. If in traffic, participants could tick which means of transport they were using. Start and end times of activities were recorded to the minute. Information on other activities was gathered by free text. After the return to the study center, the nurses checked the diary for readability, completeness and conclusiveness. Furthermore, we quantified the activities based on the classification of a metabolic equivalent unit (Peters et al., 2005).

2.3. Individual exposure

Individual noise measurements were collected by noise dosimeters (model Spark®703 by Larson Davis, Inc., USA). The microphone was attached to the collar close to the ear. Noise exposure was measured as A-weighted equivalent continuous sound pressure levels (L_{eq}) reported in units of A-weighted decibels (dB(A)). The dosimeters had a measurement range of 40–115 dB with a detector accuracy of less than 0.7 dB. They were calibrated once a week. Values lying below the lower limit of detection (LOD) were substituted with 37 dB, values above the upper LOD with 115 dB (Radon, 2007). In addition to noise, personal measurements of particle number concentrations (PNC), an indicator for ultrafine particles, were conducted using a portable condensation particle counter (CPC, model 3007, TSI Inc., USA) which covered a diameter range from 10 nm to 1 μm. For both, L_{eq} and PNC, the sampling interval was five seconds. One-minute averages were determined if at least 2/3 of the measured values in a 1-min segment were available.

To ensure that exposure data can be aligned on the same timescale with the diary data, the time of the exposure devices was synchronized with a radio-controlled clock before starting the measurement. Each participant got a wrist watch that was likewise synchronized. Furthermore, the study nurses recorded start and end times of the measurement periods in a protocol.

2.4. Long-term noise exposure

Long-term noise was modeled by the company ACCON GmbH (DIN EN ISO 14001:2009 certified), an environmental and engineering consultancy for sound and vibration technology, air pollution control and environmental planning. The RLS-90 and the interim VBUS method was used. Maximum annual A-weighted equivalent continuous sound pressure levels during the day (L_{day}, 6 am to 6 pm, unit: dB(A)) were estimated for the home address of each participant. Thereby, L_{day} was estimated separately for the sources road traffic including tram (L_{day}Road), railway system (L_{day}Railway) and aircraft traffic (L_{day}Aircraft). Except for aircraft noise the exposure assessment differed between the city and rural districts due to differences in predictor information availability. In general, the basis year was 2009 but ranged from 2000 to 2011 if predictors were not available for 2009. For more details we refer to the Supplemental material.

2.5. Statistical analyses

We generated descriptive statistics for 1-min averages of individual noise levels for all observations and separately for different whereabouts, means of transport, activities, day of the week, season and baseline characteristics of the study participants. Medians of two or more than two groups were compared by using Mann–Whitney *U* test and Kruskall–Wallis test, respectively. Descriptive statistics for long-term noise at residential addresses were also computed.

To investigate which factors explain the variability in individual noise exposure we applied additive mixed models. We used an autoregressive covariance structure to account for correlations between repeated noise measurements and included a random effect to adjust for differences between each measurement. We performed a supervised forward selection by minimizing Akaike's information criterion (Akaike, 1973). For the main model, first, we took short-term and long-term time trends into account. Continuous trend variables were considered either linearly, or smoothly as penalized spline or polynomials up to 4° (Greven et al., 2006). Second, we considered the following diary-based categorical variables: whereabouts, means of transportation, physical activity, household chores, being in a bistro, shopping, gardening and manual work, currently being at work. Further possible variables were personally measurements of PNC and relative humidity measured hourly at a fixed monitoring site in Augsburg as an indicator for rain. Finally, the baseline