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Noise annoyance — A modifier of the association between noise level and cardiovascular health?

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HIGHLIGHTS

- ► We assessed the associations between aircraft and road traffic noise and hypertension.
- ► We compared the predictive power of noise level and noise annoyance on hypertension.
- ► Road traffic noise was associated with a higher risk of hypertension.
- ► Noise annoyance had no substantial effect modifying impact on the associations.
- ► The noise level is more predictive for cardiovascular effects than noise annoyance.

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ABSTRACT

Objectives: The effect modifying impact of annoyance due to aircraft noise and road traffic noise on the relationships between the aircraft noise level and road traffic noise level on the prevalence of hypertension was investigated in 4861 subjects of the HYENA study (HYpertension and Exposure to Noise near Airports).
Methods: Different models were investigated either including the noise level and noise annoyance variables separately, or simultaneously, or together with an interaction term referring to the same noise source for the noise level and the noise annoyance.
Results: Significant effect modification was found with respect to the association between aircraft noise and hypertension. The association was stronger in more annoyed subjects. No clear interaction was found with respect to road traffic noise. The comparison of the magnitude of the main effects (per standard deviation or inter-quartile range) of noise level and noise annoyance variables revealed stronger associations with hypertension for the noise levels.
Conclusion: There is some indication that the noise level has a stronger predictive meaning for the relationship between noise exposure and hypertension than the reported noise annoyance (main effects). The results from the Hyena study support the hypothesis that noise annoyance acts as an effect modifier of the relationship between the noise level and hypertension.

1. Introduction

Environmental noise causes subjective discomfort which is assessed as reported noise annoyance (European Commission Working Group on Dose-Effect Relations, 2002; Miedema and Oudshoorn, 2001; ANSI S12.9 - Part 4, 2005). Environmental noise exposure (sound level) also causes physiological health effects, of which high blood pressure and ischemic heart diseases are the most investigated (van Kempen and Babisch, 2012; Babisch and van Kamp, 2009; Babisch, 2008). According

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to the noise reaction model (Fig. 1), two principal pathways are relevant for the development of adverse health effects due to noise (Job, 1996; Babisch, 2002). These refer to the 'direct' and the 'indirect' arousal and activation of the organism. The 'direct' pathway is determined by the instantaneous interaction of the acoustic nerve with different structures of the central nervous system. The 'indirect' pathway refers to the cognitive perception of the sound, its cortical activation and related emotional responses. Not only the noise level but also the noise annoyance has been shown to be associated with cardiovascular disorders (Ndrepepa and Twardella, 2011; Babisch, 2006). Both reaction chains can initiate physiological stress reactions, including hypothalamus, the limbic system, the autonomous nervous system, the pituitary and the adrenal gland. The general stress model is the biological mechanism for physiological dysfunction which may result in manifest physiological changes and health effects in the long run of chronic noise exposure. While the conscious experience with noise might be the primary source of stress reactions during daytime in awake subjects, the non-conscious biological response to noise may be the primary source of stress reactions during night-time in sleeping subjects — at even lower noise levels when the organism is at a much lower level of activation for physiological and mental recreation and restoration.[1] Since both factors refer – at least in parts – to different physiological mechanisms/pathways, the question arose whether the combination in a statistical model may have an additive or even synergistic effect on the physiological response (Rylander, 2004). In other words, since the noise level largely determines the noise annoyance, one would expect a stronger association between the noise level and physiological health effects in the presence of high noise annoyance (effect modification).

This article investigates the combined effects of noise level and noise annoyance on the prevalence of high blood pressure (hypertension). The particular focus was on noise annoyance as a potential effect modifier of the relationship between the noise level and the prevalence of hypertension. We refer to data of the large multi-centred European noise study HYENA (HYpertension and Exposure to Noise near Airports) where road traffic and aircraft noise data as well as annoyance data regarding both noise sources were assessed (Jarup et al., 2008). The study was approved by ethical committees within each collaborating research centre (country).

2. Materials and methods

The study design and the methods for the assessment of the exposure, hypertension and annoyance are described in detail elsewhere (Babisch et al., 2009; Jarup et al., 2005, 2008). These descriptions are summarised in the following.

2.1. Study design

The HYENA study is a large-scale multi-centred study carried out simultaneously in 6 European countries to assess the relationship between aircraft noise and road traffic noise on the one hand, and the prevalence of high blood pressure (hypertension) on the other. The study population included 4861 people (2404 men and 2467 women) aged between 45 and 70 years at the time of interview, and who had been living for at least 5 years, near one of six major European airports (London–Heathrow (GB), Berlin–Tegel (D), Amsterdam–Schiphol (NL), Stockholm–Arlanda (S), Milan–Malpensa (I) and Athens–Elephterios Venizelos (GR)). In Stockholm, also the citizens living near the City Airport (Bromma) were included to increase the number of exposed subjects. Subjects were selected at random from available registers (e.g. registration office, electoral roll, health service). To maximise exposure contrast, the population was stratified using existing noise contours. Areas with other sources of noise exposure (rail, industry, etc.) were largely excluded. Field work was carried out between 2003 and 2005.

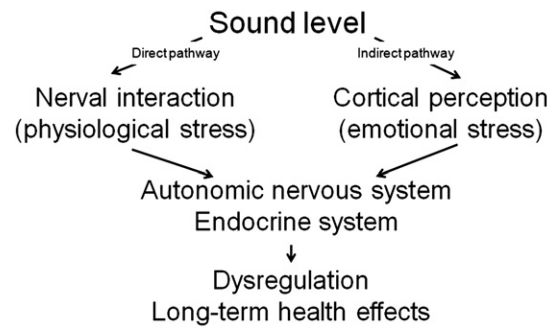

Fig. 1. Reaction model.

2.2. Noise assessment

To facilitate comparability between the HYENA countries, the 'Integrated Noise Model' (INM) served as the standard model for the assessment of the aircraft noise exposure based on radar flight tracks (Gulding et al., 2002). For aircraft noise $L_{day,12hr}$, $L_{evening,4hr}$ and $L_{night,8hr}$ were calculated (day defined as the hours from 7:00 to 19:00 or 6:00 to 18:00, evening defined as the hours from 19:00 to 23:00 or 18:00 to 22:00 and night defined as the hours from 23:00 to 7:00 or 22:00 to 6:00, according to the 'European Environmental Noise Directive' (Directive, 2002/49/EC, 2002)). In the UK the model 'Ancon' was applied which fulfilled the requirements of the European Civil Aviation Conference (ECAC, 1997). Road traffic noise assessment was based on available noise data according to the national assessment methods (United Kingdom: "Calculation of Road Traffic Noise" (Department of Transport, 1988); Germany, Italy: "Richtlinien für den Lärmschutz an Straßen" (Bundesministerium für Verkehr, 1990); Greece, The Netherlands: "Standaard Rekenen Meetvoorschrift" (Ministry of Housing, Spatial Planning and the Environment, 2002); Sweden: "Nordic Prediction Method" (Bendtsen, 1999)) and the "Good Practice Guide for Strategic Noise Mapping" (Directive, 2002/49/EC, 2002; WG-AEN, 2006). The non-weighted average 24-hour noise indicator L_{Aeq24h} was universally available for all research areas. Exposure was assessed using models with 1 dB resolution for both exposures (5 dB for UK road traffic noise) and spatial resolution of 250 m × 250 m for aircraft and 10 m × 10 m for road traffic noise. The assessment was made for the year 2002 which was assumed to be representative for the five-year period preceding the health assessment. All noise levels were linked to each participant's home address using the geographical information system technique. Road noise levels referred to the most exposed facade. To minimize the impact of inaccuracies on the noise levels at the lower end, a cut-off value of 40 dB(A) for L_{den} was introduced for aircraft noise. The lower cut-off level for the road traffic noise level L_{Aeq24h} was set to 45 dB(A). It has been shown in previous studies that aircraft noise and road traffic noise were not correlated (L_{den}(air) − L_{Aeq24h}(road): $r_s = 0.01$, L_{Aeq16h}(air) − L_{Aeq16h}(road): $r_s = 0.02$, L_{night}(air) − L_{night}(road): $r_s = 0.03$). Noise levels during the day and the night were highly correlated, which justifies the use of only one indicator for each noise source for the assessment of associations (L_{Aeq16h}(air) − L_{night}(air): $r_s = 0.82$, L_{Aeq16h}(road) − L_{night}(road): $r_s = 0.98$) (Babisch et al., 2009).

2.3. Blood pressure assessment

High blood pressure (hypertension) was defined according to the criteria of the World Health Organization (WHO), i.e. a systolic blood pressure ≥140 mmHg and/or a diastolic blood pressure ≥90 mmHg

[1] Note: The term 'noise level' is used in this article when the term 'sound level' might also be appropriate. The term 'noise' includes the subjective component of a negative attitude. However, in the praxis of engineering and noise policies, both terms are often used synonymously and interchangeable (EEA, 2010).