Hypertension and exposure to noise near airports - results of the HYENA study

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ABSTRACT

Hypertension is an important risk factor for cardiovascular disease. Even a small contribution in risk from environmental factors may have a major impact on public health. The HYENA study aimed to assess the relations between noise from aircraft or road traffic near airports and the risk of hypertension. Blood pressure was measured, and data on health (history of hypertension, medication), socio-economic, life-style factors and potential effect and exposure modifiers (personality factors, remedies to reduce the noise) were collected via questionnaire at home visits for 4,861 persons aged 45 to 70, who had lived at least five years near any of six major European airports. Aircraft noise contours and road traffic noise levels were modeled using the Integrated Noise Model (INM) and national calculation methods. The noise levels were linked to each participant's home address using graphical information systems. Significant exposure-response relationships between night-time aircraft as well as average daily road traffic noise and risk of hypertension were found after adjustment for major confounders. For night-time aircraft noise (Lnight), a 10 dB(A) increase in exposure was associated with an odds ratio of 1.14 (95 % confidence interval: 1.01-1.29). For 24h road traffic noise (Leq,24h), a 10 dB(A) increase in exposure was associated with an odds ratio of 1.10 (95% confidence interval: 1.00-1.20). The exposure-response relationships for road traffic noise was stronger for men with an odds ratio of 1.54 (95% CI: 0.99-2.40) in the highest exposure category (>65dB); (p_{trend} = 0.008). The results indicate excess risks of hypertension related to long term noise exposure, primarily for night-time aircraft noise and daily average road traffic noise.

INTRODUCTION

The number of aircraft movements in Europe is increasing at a rapid rate, recent forecasts by IATA predicting an average annual growth of 4.3 % until the year 2015. Community noise, including aircraft and road traffic noise, is the major source of nuisance in our communities. It causes annoyance, sleep disturbance and stress reactions. In the long run, aircraft noise is a risk factor for cardiovascular diseases in chronically exposed subjects, including high blood pressure and ischemic heart disease (Babisch 2006, 2008; van Kempen et al. 2002; Passchier-Vermeer & Passchier 2000). Both, the objective exposure (noise level) and the subjective perception of the noise (annoyance) are inter-related and appear on the pathway from noise exposure to clinical disorders (disease). The overall objective of the HYENA project has been to assess the impacts on cardiovascular health (primarily reflected by high blood pressure) of noise generated by aircraft and road traffic near airports. It was funded by a grant from the European Commission within the 5th Framework Programme (grant QLRT-2001-02501).

METHODS

The HYENA study (HYENA = HYpertension and Exposure to Noise near Airports) is a large-scale multi-centred study carried out simultaneously in 6 European countries. 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 the 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 population living near the City Airport (Bromma) was included to increase the number of exposed subjects. Subjects were selected at random from available registers (e.g. registration office, electoral roll, health service). Field work was carried out during the years 2003-2005. Response rates differed between 30 %-78 % between the countries. However, participation rates did not differ much between the different noise exposure categories in each country and non-responder analyses did not raise any concerns regarding selection bias. More details were given elsewhere (Babisch et al. 2007a, b; Haralabidis et al. 2008; Jarup et al. 2005, 2008).

Noise level

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 upon radar flight tracks (Gulding et al. 2002). In the UK the model 'Ancon' was applied. For aircraft noise $L_{Aeq,16hr}$ ($L_{day,16hr}$) and L_{night} were calculated (day defined as the hours from 7:00 to 23:00 or 6:00 to 22:00 according to the 'European Environmental Noise Directive' (Directive 2002/49/EC 2002)). To minimize the impact of inaccuracies on the noise levels at the lower end, cut-off values of 35 dB(A) for $L_{Aeq,16hr}$ and of 30 dB(A) for L_{night} were introduced.

Road traffic noise assessment was based on available noise data according to the national assessment methods (GB: Calculation of Road Traffic Noise; D, I: Richtlinien für den Lärmschutz an Straßen; GR, NL: Standaard Rekenen Meetvoorschrift (SRM); S: Nordic Prediction Method) and the 'Good Practice Guide for Strategic Noise Mapping' (Bendtsen 1999; Bundesministerium für Verkehr 1990; Department for Transport and Welsh Office 1988; European Commission Working Group 2003; Ministry of Housing Spatial Planning and the Environment 2002). Noise levels were modeled for

2002; this year was assumed to be representative for the five-year period preceding the health assessment. In most countries only aggregated 24-hour data on the intensity of road traffic were available. $L_{Aeq,24hr}$ and L_{night} were derived from these data, and thus highly correlated (overall $r_p = 0.97$). The calculation was made with reference to the nearest facades of the houses. To minimize the impact of inaccuracies on the noise levels at the lower end, cut-off values of 45 dB(A) for $L_{Aeq,24hr}$ and of 35 dB(A) for L_{night} were introduced.

Modeled noise exposure levels were linked to each participant's home address using geographic information systems (GIS) technique. The spatial resolution (grid size) was 250 x 250 m for aircraft and 10 x10 m for road traffic noise. For both aircraft and road traffic noise the levels had a 1 dB resolution, except for the UK where only 5 dB classes for road traffic noise could be procured. The midpoints of these classes were chosen for the analyses using continuous exposure data.

Noise annoyance

During the home visits personal interviews were carried out. The standardized questionnaire consisted of questions regarding health status, socio-demographic, lifestyle and behavioral factors, annoyance and personality factors. Noise annoyance was assessed using the non-verbal 11-point ICBEN scale, because verbal translations were only available in English, German and Dutch (Fields et al. 2001). The Greek, Swedish and Italian partners of HYENA had to make their own translations. This was done carefully by the partners using back- and forward translation. Native English speakers were involved, and existing material in the partner countries was considered for the translation process. The battery of annoyance items referred to air traffic, road traffic and other community noise or indoor noise sources (e.g. railway, motorcycles, industry, construction, neighbors and indoor installations). A distinction was made between source-specific noise annoyances during the day and the night, and between the global noise annoyance with open and closed windows.

Confounding factors and effect modifiers

A number of potential confounders were assessed in the HYENA study. The following were used for adjustment in the statistical analyses country (categorical), age (continuous), gender (categorical), years of education (categorical: quartiles standardized by country means in order to account for differences in education systems between countries), alcohol intake (continuous: units per week), body mass index (continuous), physical activity (categorical: exercise <1 time/week, 1-3 times/week, >3 times/week). Smoking (categorical: non-smoker, ex-smoker, 1-10/day, 11-20/day, >20/day) and salt intake (categorical: always add to meals yes/no) were also assessed but did not show a significant association with blood pressure or had a considerable impact on the associations between noise and high blood pressure.

As part of the interview potential effect modifiers were assessed. These included personality and behavioral factors were assessed, including noise sensitivity (10 items, 6 point Weinstein scale, dichotomous variable (cut = median) (Stansfeld & Shine 1993)) and coping style (4 items, 2 point scale, sum score, dichotomous variable (cut = mean) (van Kamp 1990)), belief in authorities (5 items, 6 point scale, sum score, dichotomous variable (cut = median, standardized by country) (van Kamp 1990)) and attitude towards the airport (1 item 11 point scale, dichotomous variable (cut = median)). Furthermore, the frequency of usage of noise reducing remedies (during the day or during the night) was assessed (e.g. ear plugs, closing windows, closing window shutters, other, dichotomous variable (if any of them 'often' or 'always' used:

coding =1, otherwise coding =0)). These variables were treated as covariates in the present data analyses and were used for stratification of the statistical models. Subgroup analyses were carried out with respect to years of residence in the present home (>15years), annoyance ('highly' annoyed = categories 8,9,10 on the 11 point scale) and other factors.

High blood pressure

Blood pressure (BP) measurements were carried during the home visits under standardized conditions using validated automated blood pressure instruments (e. g. OMRON M5-1). Subjects were classified as hypertensive according to the WHO criterion (systolic BP >= 140 mmHg or diastolic BP >= 90 mmHg), or the prevalence of doctor-diagnosed hypertension ("Have you ever been diagnosed as having high blood pressure?"), or antihypertensive medication in conjunction with a diagnosis of hypertension (ATC-codes C02, C03, C07, C08, C09).

RESULTS

Main findings:

Multiple logistic regression analyses were carried out to assess the associations between aircraft noise, road traffic noise and high blood pressure (variable 'HT-Main'). Aircraft noise during the day ($L_{day,16hr}$, range: ≤ 35 to 75 dB(A)), aircraft noise during the night (L_{night}, range: ≤ 30 to 70 dB(A)) and road traffic noise ($L_{Aeq,24hr}$, range: ≤ 45 to 77 dB(A)) were considered simultaneously in the model, controlling for confounders. The results are shown in Table 1 (model 1). An increase of aircraft noise during the day of 10 dB(A) was associated with a relative risk (odds ratio) of OR = 0.93 (95% confidence interval CI = 0.83-1.04, p = 0.190), an increase of aircraft noise during the night with a relative risk of OR = 1.14 (CI = 1.01-1.29, p = 0.031), and an increase of road traffic noise over 24 hours with a relative risk of OR = 1.10 (CI = 1.00-1.20, p = 0.044) (Jarup et al. 2008). Since both aircraft noise indicators were highly correlated (r_p = 0.8) also models were calculated where only one aircraft and one road traffic noise indicator were considered (models 2,3). While the road noise effect remained the same, the aircraft noise effects diminished slightly, but was still borderline significant (OR = 1.07, p = 0.068). Aircraft noise during the day was not significantly associated with hypertension. When the potential effect modifiers were additionally considered as covariates in the model, the odds ratios of $L_{day,16hr}$ (air), L_{night} (air) and $L_{Aeq,24hr}$(road) did not change (model 4). Although not being significant, coping style, noise sensitivity, attitude towards the airport, belief in authorities, and use of remedies during the night were negatively associated with high blood pressure (use of remedies during the day positively).

Stratified analyses

The effect estimates were larger in males than in females, particularly with respect to road traffic noise (models 5,6). Lengths of residence (living for more than 15 years in the present home (n = 2827)) had no impact on the effects of aircraft noise on hypertension (model 7). The odds ratio for road traffic noise, however, was slightly larger in subjects with longer lengths of residence (OR = 1.16, p = 0.013). The association between aircraft noise during the night and hypertension was stronger for subjects that were 'highly' annoyed by aircraft noise during the day (OR = 1.24, p = 0.015, n = 1383, models 9,11) compared to less annoyed subjects (OR = 1.04, p = 0.421, n = 3473, models 8,10). When the same kind of stratification was made with respect to the annoyance due to aircraft noise during the night, no such difference between the two subgroups was found (models 13,15 vs. models 12,14). The orientation of rooms was a-priory not considered to have an impact as an effect modifier on the associations regarding aircraft noise, because the noise coming from the top is not shielded by the houses themselves (no quiet side). However, stratification according to the type of housing revealed different odds ratios in the subgroups. Although not being significant, a slightly larger effect estimate for the association between aircraft noise during the night and hypertension was found for subjects that lived in flats and apartments (OR = 1.22, p = 0.186, n = 1389, model 17) than for subjects that lived in whole houses or bungalows (OR = 1.13, p = 0.065, n = 3459, model 16). With respect to road traffic noise, however, a difference of the odds ratios between the subgroups was much larger (OR = 1.26, p = 0.004 vs. OR = 1.03, p = 0.095).

Noise sensitivity had no effect modifying impact on the associations (models 18,19). The association between road traffic noise and high blood pressure was stronger in subjects that used noise reducing remedies during the day or the night regularly (OR = 1.18, p = 0.017, n = 2113, model 21 vs. OR = 1.08, p = 0.248, n = 2724, model 20), indicating that the use of noise reducing remedies was not effective. However, when the subjects were asked whether they kept the living room windows closed when they were in the room (during winter and summer), a slightly smaller odds ratio for the association between road traffic noise and hypertension was found in the subgroup that always kept the windows closed (closed windows: OR = 1.06, p = 0.503, n = 1171, model 23 vs. opened windows: OR = 1.13, p = 0.029, n = 3653, model 22). Similar results for road traffic noise were found with respect to the window opening habits of the bedroom (closed windows: OR = 1.02, p = 0.732, n = 2232, model 25 vs. opened windows: OR = 1.19, p = 0.008, n = 2576, model 24). No such tendencies were found for aircraft noise. 'Attitude towards the airport' seemed to have an effect modifying impact on the results. The association between aircraft noise during the night and hypertension was stronger in subjects with no positive attitude (OR = 1.22, p = 0.027, n = 2475, model 26 vs. OR = 1.07, p = 0.414, n = 2342, model 27). However, the effect disappeared when aircraft noise during the day was excluded from the model, which was associated with lower blood pressure (collinearity of multiple variables). When the analysis was stratified according to 'belief in authorities' the association between road traffic noise and hypertension was stronger in subjects without belief that the authorities would do something about the noise (OR = 1.16, p = 0.021, n = 2640, model 30 vs. OR = 1.03, p = 0.708, n = 2199, model 31). There was no noticeable indication of an effect modifying impact of 'coping style' on the results (models 28, 29).

CONCLUSION

The Hyena study supports previous studies that have suggested an effect of long-term road traffic noise on high blood pressure (Babisch 2006, 2008). In particular, the prevalence of hypertension increased with increasing noise exposure. The findings also indicate an effect of night-time aircraft noise on hypertension. Stratified analyses (subgroups) suggested that annoyance due to aircraft noise during the day could be an effect modifier of the association between aircraft noise during the night and hypertension (larger odds ratio in annoyed subjects), and that closing the windows was an effect modifier of the association between road traffic noise and hypertension (smaller odds ratio in subjects who kept the windows closed). Type of housing and belief in the authorities were also found to have a potentially effect modifying impact on the association between road traffic noise and high blood pressure.

Table 1: Associations between aircraft noise, road traffic noise and high blood pressure

Model	Noise Indicator A = Air R = Road	Covariates	Odds Ratio OR per 10 dB(A)	95% Confidence Interval CI	Significance p-value
1	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders	0.928 1.141 1.097	0.829-1.038 1.012-1.286 1.003-1.201	0.190 0.031 0.044
2	A: $L_{day,16hr}$ R: $L_{Aeq,24hr}$	Confounders	1.021 1.101	0.953-1.095 1.006-1.205	0.550 0.037
3	A: L_{night} R: $L_{Aeq,24hr}$	Confounders	1.071 1.099	0.995-1.154 1.004-1.202	0.068 0.041
4	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Effect modifiers	0.919 1.143 1.092	0.819-1.031 1.013-1.289 1.008-1.182	0.170 0.030 0.030
5	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: males	0.891 1.166 1.181	0.760-1.045 0.986-1.379 1.039-1.341	0.149 0.073 0.011
6	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: females	0.955 1.112 1.023	0.814-1.012 0.937-1.032 0.899-1.163	0.571 0.225 0.732
7	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: length of residence	0.878 1.133 1.158	0.759-1.016 0.975-1.318 1.031-1.301	0.080 0.103 0.013
8	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: not highly annoyed by aircraft noise during day	0.995 1.041 1.092	0.871-1.137 0.902-1.202 0.985-1.212	0.938 0.580 0.095
9	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: highly annoyed by aircraft noise during day	0.733 1.467 1.099	0.759-1.016 0.975-1.318 1.031-1.301	0.033 0.001 0.317
10	A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: not highly annoyed by aircraft noise during day	1.037 1.093	0.902-1.202 0.985-1.212	0.421 0.094
11	A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: highly annoyed by aircraft noise during day	1.244 1.110	1.043-1.483 0.922-1.336	0.015 0.269
12	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: not highly annoyed by aircraft noise during night	0.942 1.128 1.090	0.819-1.043 0.990-1.285 0.988-1.202	0.200 0.071 0.085
13	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: highly annoyed by aircraft noise during night	1.052 1.082 1.122	0.739-1.498 0.781-1.499 0.883-1.426	0.777 0.635 0.345
14	A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: not highly annoyed by aircraft noise during night	1.055 1.092	0.972-1.146 0.990-1.204	0.200 0.079
15	A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: highly annoyed by aircraft noise during night	1.122 1.122	0.908-1.385 0.883-1.425	0.286 0.347
16	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: whole house, bungalow or mobile home	0.995 1.134 1.028	0.805-1.045 0.992-1.296 0.917-1.152	0.938 0.580 0.095
17	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: flat, maisonette or apartment	0.917 1.221 1.258	0.711-1.181 0.909-1.640 1.078-1.468	0.501 0.186 0.004
18	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: noise sensitivity < median	0.930 1.121 1.100	0.795-1.089 0.951-1.322 0.966-1.254	0.366 0.172 0.151

19	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: noise sensitivity ≥ median	0.953 1.139 1.108	0.809-1.122 0.955-1.359 0.977-1.256	0.563 0.147 0.110
20	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: no noise reducing remedies during day or night	0.947 1.142 1.077	0.918-1.094 0.972-1.343 0.950-1.222	0.458 0.107 0.248
21	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: noise reducing remedies during day or night	0.944 1.127 1.180	0.784-1.137 0.937-1.356 1.030-1.352	0.544 0.204 0.017
22	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: living room windows not always closed	0.914 1.140 1.126	0.700-1.045 0.984-1.321 1.012-1.253	0.189 0.082 0.029
23	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: living room windows always closed	1.009 1.169 1.062	0.809-1.260 0.946-1.444 0.891-1.266	0.935 0.149 0.503
24	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: bedroom windows not always closed	0.978 1.090 1.188	0.843-1.135 0.938-1.266 1.045-1.353	0.770 0.262 0.008
25	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: bedroom windows always closed	0.910 1.167 1.024	0.760-1.090 0.948-1.437 0.899-1.167	0.307 0.146 0.723
26	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: no positive attitude towards the airport	0.853 1.217 1.093	0.724-1.006 1.023-1.449 0.961-1.244	0.059 0.027 0.177
27	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: positive attitude towards the airport	0.999 1.072 1.092	0.851-1.174 0.907-1.269 0.960-1.241	0.995 0.414 0.179
28	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: no coping	0.906 1.104 1.069	0.782-1.050 0.943-1.305 0.924-1.238	0.190 0.248 0.370
29	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: coping	0.969 1.135 1.120	0.851-1.174 0.907-1.269 0.960-1.241	0.729 0.171 0.054
30	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: no belief in authorities	0.917 1.157 1.155	0.784-1.071 0.984-1.359 1.022-1.307	0.273 0.077 0.021
31	A: $L_{day,16hr}$ A: L_{night} R: $L_{Aeq,24hr}$	Confounders Subgroup: belief in authorities	0.929 1.120 1.026	0.786-1.098 0.934-1.343 0.897-1.174	0.386 0.221 0.708

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