ORIGINAL ARTICLE

Does aircraft noise exposure increase the risk of hypertension in the population living near airports in France?

Anne-Sophie Evrard,[1] Marie Lefèvre,[1] Patricia Champelovier,[2] Jacques Lambert,[2,3] Bernard Laumon[4]

[1]Univ Lyon, Université Claude Bernard Lyon1, IFSTTAR, UMRESTTE, UMR T_9405, F-69675, Bron, France
[2]IFSTTAR, Planning, Mobilities and Environment Department, Transport and Environment Laboratory (LTE), Cité des Mobilités, 25 avenue François Mitterrand, F-69675, Bron, France
[3]Currently retired, Villeurbanne, France
[4]IFSTTAR, Transport, Health and Safety Department, Cité des Mobilités, 25 avenue François Mitterrand, F-69675, Bron, France

Correspondence to
Dr Anne-Sophie Evrard, IFSTTAR, Cité des Mobilités, 25 avenue François Mitterrand, Bron F-69675, France; anne-sophie.evrard@ifsttar.fr

Received 15 February 2016
Revised 20 June 2016
Accepted 5 July 2016
Published Online First 1 August 2016

Linked

▸ http://dx.doi.org/10.1136/oemed-2016-103988

To cite: Evrard A-S, Lefèvre M, Champelovier P, *et al. Occup Environ Med* 2017;**74**:123–129.

ABSTRACT

Objectives The largest study until now around 6 major European airports, the HYENA (HYpertension and Exposure to Noise near Airports) study, reported an excess risk of hypertension related to long-term aircraft noise exposure. The DEBATS (Discussion on the health effects of aircraft noise) study investigated the relationship between this exposure and the risk of hypertension in men and in women near French airports.
Methods Blood pressure of 1244 participants older than 18 years of age was measured. Information about health, socioeconomic and lifestyle factors was collected by means of a face-to-face questionnaire performed at home by an interviewer. Aircraft noise exposure was assessed for each participant's home address using noise maps. They were calculated with the Integrated Noise Model with a 1 dB(A)-resolution. The major potential confounders being risk factors for hypertension were included in the logistic regression models: age, occupational activity, body mass index, physical activity and alcohol consumption.
Results After adjustment for the main potential confounders, an exposure–response relationship was evidenced between the risk of hypertension and aircraft noise exposure at night for men only. A 10-dB(A) increase in L_{night} was associated with an OR of 1.34 (95% CI 1.00 to 1.97).
Conclusions These findings contribute to the overall evidence suggesting that aircraft noise exposure at night-time may increase the risk of hypertension in men. Hypertension is a well-known and established risk factor for cardiovascular disease. The association reported in the present study between aircraft noise and hypertension implies that aircraft noise might be a risk factor also for cardiovascular disease.

What this paper adds

- The DEBATS study is the first to investigate the relationship between long-term aircraft noise exposure and the risk of hypertension in men and in women near French airports. After adjustment for the main potential confounders, an exposure–response relationship was evidenced between the risk of hypertension and aircraft noise exposure at night for men only.
- The findings of this study contribute to the overall evidence suggesting that aircraft noise exposure at night-time may increase the risk of hypertension in men.
- Hypertension is a well-known and established risk factor for cardiovascular disease. The association reported in the present study between aircraft noise and hypertension implies that aircraft noise might be a risk factor also for cardiovascular disease.

INTRODUCTION

Since 2002 and the adoption of the European Union Environmental Noise Directive, an increasing number of large epidemiological studies have been conducted focusing on cardiovascular disease. Noise is a psychosocial stressor that activates the sympathetic and endocrine system. According to the general stress model,[1] neuroendocrine arousal is associated with adverse metabolic outcomes that are well-known and established risk factors for cardiovascular disease. The majority of studies on the cardiovascular effects of aircraft noise have focused on blood pressure (BP) and hypertension. The largest study until now on aircraft noise, the HYENA (HYpertension and Exposure to Noise near Airports) study, included 4861 persons between 45 and 70 years of age at the time of interview, living near one of six major European airports (London Heathrow (UK), Berlin Tegel (Germany), Amsterdam Schiphol (the Netherlands), Stockholm Arlanda (Sweden), Milan Malpensa (Italy) and Athens Eleftherios Venizelos (Greece) Airports).[2] This study reported an excess risk of hypertension related to long-term night-time aircraft noise exposure with an OR of 1.14, 95% CI 1.01 to 1.29 per 10 dB(A) increase in the night average weighted sound pressure level (L_{night}). The results of this study also suggested an effect of aircraft noise exposure on the use of antihypertensive medication for the UK and the Netherlands,[3] as did those of the study around Schiphol Airport (Amsterdam) on the use of medication for cardiovascular diseases/increased BP.[4] In 2009, Babisch and van Kamp[5] produced a meta-analysis of results from five studies on aircraft noise and hypertension including the HYENA study. The relative risk based on this meta-analysis was estimated to OR=1.13, 95% CI 1.00 to 1.28 for a 10 dB(A) increase in the day/night average weighted sound pressure level (L_{dn}) of aircraft noise within the range of 45–70 dB(A).

Gender differences regarding the risk of hypertension related to aircraft noise exposure have been sparsely studied. In Sweden, Eriksson *et al*[6] suggested an increased risk of hypertension related to long-term aircraft noise exposure in men but not in women. The HYENA study indicated no difference in risk of hypertension between men and women related to aircraft noise exposure.[2] However, the same study reported an increased risk of hypertension in men but not in women following long-term exposure to road traffic noise. Such a difference occurred in other studies,[7 8] although the evidence is not fully consistent.[9–11]

No epidemiological study has yet been carried out in France on the health effects of aircraft noise. The objective of the DEBATS (Discussion on the health effects of aircraft noise) research programme was to characterise the relationships between aircraft noise exposure and the health status of the French population living in the vicinity of airports. DEBATS includes in particular a longitudinal field study that aims to follow-up ~1200 of French airports residents during 4 years. The participants have been interviewed in 2013 and they will be interviewed again in 2015 and in 2017.

On the basis of the data collected in 2013 at the participants' inclusion in this longitudinal study, the present paper addresses more specifically the issue of an association between aircraft noise exposure and the risk of hypertension in men and in women.

METHODS

Study population

The study population included persons older than 18 years of age at the time of interview, living near one of the three following French airports: Paris–Charles de Gaulle, Toulouse–Blagnac and Lyon–Saint-Exupéry. In order to ensure that sufficient numbers of participants were exposed to high aircraft noise levels and then in order to maximise exposure contrast, we used a stratified sample of the population based on recent aircraft noise contours. These contours are based on the day–evening–night equivalent level (L_{den}), which is defined as a weighted average of sound pressure levels from day (06:00 to 18:00), evening (18:00 to 22:00) and night (22:00 to 06:00). In this calculation, evening and night sound pressure levels receive a 5 dB(A) penalty (A-weighted average sound pressure level) and 10 dB(A), respectively, to reflect people's noise sensitivity.[12] The noise contours defined four 5 dB(A)-categories of aircraft noise exposure in terms of L_{den}: <50, 50–54, 55–59 and ≥60 dB(A), the selection process planned to select 300 participants in each of these four categories.

Questionnaire

For their inclusion in the longitudinal study in 2013, participants filled out a questionnaire during a face-to-face interview at their place of residence. Information was collected by an interviewer about demographic variables, socioeconomic status, lifestyle factors including smoking and alcohol consumption and physical activity, personal medical history in terms of sleep disturbances, cardiovascular diseases and anxiety and depressive disorders, medication use, and finally annoyance from aircraft noise exposure. Anthropometric measurements (weight, height and waist circumference) were also recorded. Length of residence was assessed in order to limit sensitivity analyses to participants who had been living at their residence for more than 5 years, thus experiencing aircraft noise pollution for a significant period of time.

Blood pressure

The interviewer measured the systolic BP (SBP) and the diastolic BP (DBP) and the heart rate (HR) of the participants in a sitting position with validated and automated BP instruments. BP and HR were assessed three times: the first measurement was recorded at the beginning of the interview after a 5 min rest; a second measurement was recorded after a further 1 min rest. A third measurement was taken at the end of the interview (~1 hour later). The mean of the first two readings was used to define SBP, DBP and HR for the subsequent analyses. The third reading was used as a validity control: 73 participants with a difference higher than 20 mm Hg between the mean of the first two readings and the third reading were excluded from the sensitivity analyses. Moreover, using the mean of the last two readings did not change the results.

Hypertension was defined according to the WHO:[13] a SBP≥140 mm Hg or a DBP≥90 mm Hg. In the analyses, the measurements were combined with information on diagnoses of hypertensive disease and medication. Participants were classified as hypertensive if they had either BP levels above the WHO cut-off points or a diagnosis of hypertension by a physician in conjunction with use of antihypertensive medication, as reported in the interview questionnaire. Participants were considered to have a diagnosis of hypertension if they answered 'yes' to the question 'During the last 12 months, have you ever been told by a doctor or health professional that you had hypertension?'. Treatment of BP was defined by use of antihypertensive agents during the past 12 months.

Confounding factors

The major potential confounders were included in the statistical models: age (continuous), body mass index (BMI, body weight divided by height squared) as a continuous variable, physical activity (yes/no), education (<French high-school certificate/=French high-school certificate/>French high-school certificate) and alcohol consumption (no/light/moderate/heavy). All potential confounders with a p value of 0.30 or less in univariate analysis were entered in the multivariate models. An association between occupational activity and the risk of hypertension was observed in this study. Since education and occupational activity were strongly correlated, occupational activity instead of education was included in the final model.

Smoking is a well-established risk factor for cardiovascular disease, but its effect on hypertension is less clear. To assess whether smoking would confound the effects of noise on hypertension, smoking was initially included in the regression model. However, smoking did not contribute significantly to the model and did not have any impact on the effect estimate of noise, so smoking was not included in the final model.

To assess whether the country of birth (used as a proxy for ethnicity), financial difficulty, work-related stress and major life events, annoyance from aircraft noise exposure, the average number of awakenings per night, noise sensitivity and house characteristics (such as window opening, insulation of roof and/or windows) would confound the effects of noise on hypertension or on DBP or SBP, these variables were initially included in the multivariate regression models. However, they did not contribute significantly to the model and did not have any impact on the effect estimate of noise, so they were not included in the final model.

The area of study was initially included in the multivariate model as a confounder in order to take geographic region into account. However, aircraft noise levels were strongly correlated

Evrard A-S, *et al*. *Occup Environ Med* 2017;**74**:123–129. doi:10.1136/oemed-2016-103648

with the airports (mean of aircraft noise exposure in terms of L_{den}: 49, 54 and 56 dB(A) near Lyon–Saint-Exupéry, Toulouse–Blagnac and Paris–Charles de Gaulle Airports, respectively). This correlation led to overadjustment when aircraft noise levels and the area of study were both introduced in the multivariate model. Therefore, the area of study was not included in the final model.

The covariates included in the final fully adjusted regression model were: age, BMI, physical activity, alcohol consumption, occupational activity and aircraft noise level.

Aircraft noise exposure assessment

The French Civil Aviation Authority and Paris Airports produce outdoor noise exposure maps with the 'Integrated Noise Model' (INM)[14] for France's largest airports. The INM is an internationally well-established computer model that evaluates aircraft noise impacts in the vicinity of airports and outputs noise contours for an area (figure 1). Those contours, described in the 'Study population' paragraph, were used to select the participants in the study.

For the statistical analyses, different noise indicators in decibels A (dB(A)) were used: L_{den}, $L_{Aeq,\ 16\ hour}$, which is the A-weighted equivalent continuous noise level between 06:00 and 22:00, and L_{night}, which is the A-weighted equivalent continuous noise level between 22:00 and 06:00.[12] They were estimated with a 1-dB(A) resolution from a minimum of L_{den} 45 dB (A), $L_{Aeq,\ 16\ hours}$ 35 dB(A) and L_{night} 30 dB(A). Aircraft noise levels below these values were assigned 44 dB(A) for L_{den}, 34 dB (A) for $L_{Aeq,\ 16\ hours}$ and 29 dB(A) for L_{night}. These estimated aircraft noise levels were linked to the residential addresses of the participants using the geographic information system (GIS) technique.

The aircraft noise levels calculated with INM were compared with aircraft noise measurements obtained through existing noise monitoring systems[15] for Paris–Charles de Gaulle Airport or through a specific campaign[16] for Lyon–Saint-Exupéry Airport. Most of the differences in terms of L_{den} were between 0.5 and 1.5 dB(A), showing the accuracy of the estimations.

Statistical analysis

The age-adjusted prevalence for hypertension was calculated for each gender and both genders together using as standard population the age structure of the French population in 2014, derived from the latest French national census. The sex-adjusted and age-adjusted (to the European standard population) prevalence of hypertension was also calculated in order to compare the prevalence of hypertension in France with those in other European countries.

Logistic regression models with hypertension as the outcome variable, and aircraft noise exposure and confounders as covariates, were used to assess the associations of aircraft noise with hypertension. Linear regression models with DBP and SBP as the outcome variables, and aircraft noise exposure and the same confounders as those included in logistic regression models, were used to assess the associations of aircraft noise with DBP and SBP. Generalized Additive Models[17 18] including a smooth cubic spline function were first adjusted in order to account for a potential non-linear effect of aircraft noise on hypertension or on DBP or SBP. Since they suggested approximately linear relationships, associations with the continuous exposure variable were estimated and presented in the present paper. Statistical analyses were stratified on gender.

Statistical analyses were conducted using SAS version 9.3 (SAS Software [program] 9.3 version. USA: Cary North Carolina, USA 2011).

RESULTS

In total 1244 participants (695 women and 549 men) aged 18 years and older at the time of the interview were included in the DEBATS longitudinal study: 317, 307, 314 and 306 for aircraft noise categories <50, 50–54, 55–59 and ≥60 dB(A) in terms of L_{den}, respectively. Overall, the participation rate was 30%. Participation rates differed among the three airports: 25% for Paris–Charles de Gaulle Airport, 34% for Toulouse–Blagnac Airport and 39% for Lyon–Saint-Exupéry Airport. Participation rates did not differ much among the different noise exposure categories. Overall, response rates were 29%, 33%, 30% and 28% for aircraft noise categories <50, 50–54, 55–59 and ≥60 dB(A), respectively.

Analyses related to the risk of hypertension involved 1230 participants (687 women and 543 men). Forty-one per cent of men and 30% of women were classified as hypertensive (table 1). The age-adjusted prevalence of hypertension (to the French population) was 37% in men and 31% in women. The sex-adjusted and age-adjusted prevalence of hypertension was 34%. The sex-adjusted and age-adjusted (to the European standard population) prevalence of hypertension among people between 45 and 70 years of age was 43%.

Table 2 shows the ORs for hypertension in relation to the a priori major confounders. Age and BMI were significantly associated with the risk of hypertension in both genders. Alcohol consumption and occupational activity were significantly associated with the risk of hypertension in men but not in women.

Table 3 displays the effects estimates of three aircraft noise indicators (L_{den}, $L_{Aeq,\ 16\ hours}$ and L_{night}) on hypertension and BP (DBP and SBP) in men. A rise in OR of hypertension with increasing exposure was shown for day–evening–night aircraft noise exposure (L_{den}) and for night-time noise exposure (L_{night}) in men but not in women (results not shown). No such trend was found for aircraft noise exposure during the day ($L_{Aeq,\ 16\ hours}$). The models including an interaction term between gender and noise were also performed: they confirmed that the risk of hypertension was associated with aircraft noise exposure only among men (results not shown). A significant increase in DBP and in SBP was also found for each of the three aircraft noise indicators among men. A significant increase only in SBP was shown among women for L_{den} and $L_{Aeq,\ 16\ hours}$ (results not shown).

DISCUSSION

The age-adjusted (to the French population) prevalences of hypertension in men and in women estimated in the DEBATS study were very similar to those observed in the ENNS (National Nutrition Health Survey) study in participants between 18 and 74 years of age in France in 2006. In the ENNS study, the prevalence of hypertension was 34% in men and 28% in women.[19] The sex-adjusted and age-adjusted (to the European standard population) prevalence of hypertension among people between 45 and 70 years of age (43%) was lower than those found in the HYENA study: 49% in the UK, 55% in Germany, 52% in the Netherlands, Sweden and Italy, and 57% in Greece.[2]

These results suggest that aircraft noise exposure at night-time is associated with an increased risk of hypertension in men but not in women. This association was confirmed by those

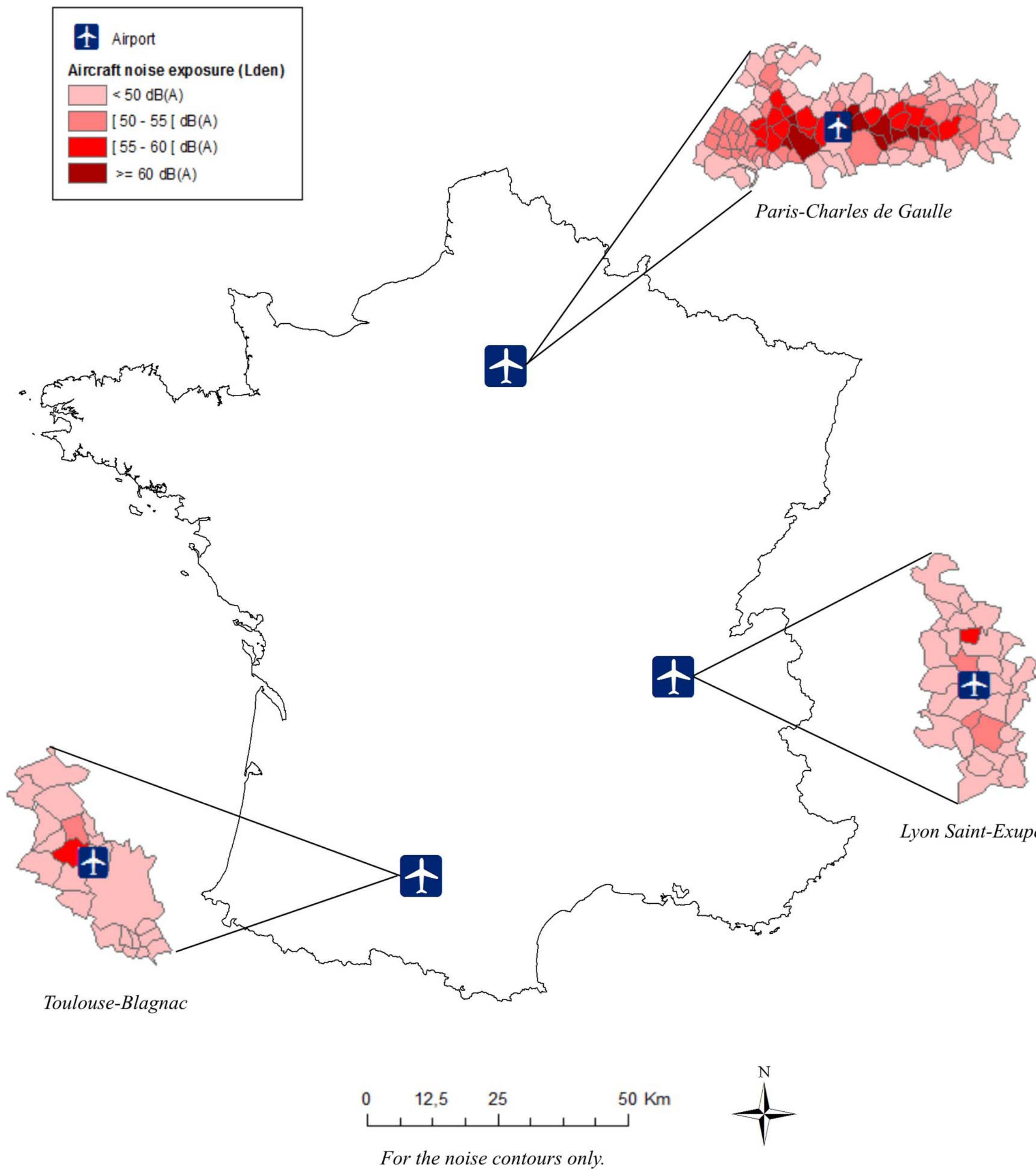

Figure 1 Noise contours of the three airports. L_{den}, day–evening–night equivalent level.

observed with DBP and SBP in men only. Controlling for the a priori major confounding factors (age, BMI, alcohol consumption, physical activity and occupational activity) did not change the results. In this study, the assessment of extensive covariate data made it possible to evaluate a large number of possible confounding factors and ensure the stability of the results. However, uncontrolled or residual confounding, exposure and disease misclassification, and selection bias all need to be considered. Since the association between aircraft noise exposure and the risk of hypertension remained similar when the average number of awakenings per night or annoyance from aircraft noise exposure was included in the models, this study does not support the hypothesis that the effects of noise exposure on hypertension are mediated through sleep disturbances and/or annoyance. This could indicate either that there would be another physiological mechanism to explain this association, or that the evidenced association would reflect residual confounding because the selected variables (the average number of awakenings per night and annoyance from aircraft noise exposure) do not effectively characterise sleep disturbance and annoyance, respectively.

The results were also unchanged when the analysis was restricted to the 978 participants who had resided at their address for at least 5 years or when the 106 participants who took drugs that could relate to BP modification were excluded. We do not have information on family history of the participants, but it is very unlikely that this variable would be correlated with aircraft noise exposure, thus confounding the association between this exposure and the risk of hypertension. Exposure to road traffic noise and to railway noise was estimated only around Paris–Charles-de-Gaulle Airport and the estimation was inaccurate, thus reducing the statistical power to evidence any association between exposure to aircraft noise and the risk of hypertension if it was introduced in the models.

Table 1 Descriptive statistics of the study population

Gender / Variable	Men n=543 n	(%)	Women n=687 n	(%)
Age (years)				
18–34	73	(13)	150	(22)
35–44	104	(19)	130	(19)
45–54	133	(25)	132	(19)
55–64	115	(21)	144	(21)
65–74	93	(17)	90	(13)
≥75	25	(5)	41	(6)
Hypertension				
No	320	(59)	484	(70)
Yes	223	(41)	203	(30)
BMI				
Underweight or normal weight	186	(34)	368	(54)
Overweight	234	(43)	185	(27)
Obesity	120	(22)	128	(19)
Physical activity				
No	251	(46)	327	(48)
Yes	292	(54)	360	(52)
Alcohol consumption				
No	102	(19)	240	(35)
Light	320	(60)	310	(45)
Moderate	85	(16)	107	(16)
Heavy	29	(5)	25	(4)
Smoking				
Non-smoker	242	(45)	373	(54)
Ex-smoker	179	(33)	149	(22)
Occasional smoker	8	(2)	11	(2)
Smoker	113	(21)	154	(22)
Occupational activity				
No	210	(39)	277	(40)
Yes	333	(61)	410	(60)
Length of residence, years				
<5	108	(20)	144	(21)
5–9	111	(20)	138	(20)
10–14	83	(15)	125	(18)
15–19	58	(11)	63	(9)
≥20	183	(34)	217	(32)
Noise level, dB(A)				
Study area: Paris				
<50	61	(22)	47	(14)
50–54	45	(16)	56	(16)
55–59	84	(30)	124	(36)
≥60	87	(31)	115	(34)
Total	277		342	
Study area: Toulouse				
<50	37	(23)	66	(28)
50–54	50	(31)	52	(22)
55–59	35	(21)	61	(26)
≥60	41	(25)	57	(24)
Total	163		236	
Study area: Lyon				
<50	55	(53)	50	(14)
50–54	45	(44)	56	(16)
55–59	2	(2)	3	(36)
≥60	1	(1)	0	(34)
Total	103		109	

BMI, body mass index.

Table 2 ORs for hypertension in relation to the a priori major confounders

Gender / Variable	Men OR (95% CI)	p Value	Women OR (95% CI)	p Value
Age	1.09 (1.07 to 1.12)	<0.0001	1.06 (1.05 to 1.08)	<0.0001
BMI	1.11 (1.06 to 1.16)	<0.0001	1.09 (1.05 to 1.13)	<0.0001
Physical activity		0.11		0.28
No	1.00		1.00	
Yes	0.72 (0.48 to 1.08)		0.81 (0.55 to 1.19)	
Alcohol consumption		0.02		0.15
No	1.00		1.00	
Light	0.51 (0.30 to 0.88)		1.56 (1.02 to 2.39)	
Moderate	0.72 (0.36 to 1.43)		1.11 (0.63 to 1.97)	
Heavy	1.40 (0.53 to 3.73)		1.89 (0.73 to 4.87)	
Occupational activity		0.001		0.48
No	1.00		1.00	
Yes	2.73 (1.50 to 4.98)		1.18 (0.75 to 1.84)	

All the variables were included simultaneously in the model.
BMI, body mass index.

Currently, ultrafine particle (UFP) emissions from aircrafts and their health effects around airports are an important issue.[20] This exposure would have confounded the results of this study. Unfortunately, exposure data based on this indicator are not yet available around airports in France.

This study seems to confirm the findings of previous studies suggesting that aircraft noise exposure is associated with the risk of hypertension.[3–5 21–23] This association was positive and significant only for men but not for women. This gender difference might be due to some unmeasured confounding factors that would be more prevalent among men than women. However, it is consistent with the results of Eriksson *et al*[6] in Sweden: a significant risk increase per 5 dB(A) of aircraft noise exposure was found in men (relative risk (RR)=1.21, 95% CI (1.05 to 1.39)), but not in women (RR=0.97, 95% CI (0.83 to 1.13)). The HYENA study did not suggest any difference in risk of hypertension between men and women related to aircraft noise exposure.[2] However, the same study reported an increased risk of hypertension in men but not in women following long-term exposure to road traffic noise. Such a difference occurred in other studies,[7 8] although the evidence is not fully consistent.[9–11] Gender differences in the pathogenesis of cardiovascular diseases could be part of the explanation for the diverging results presented in this study.[24 25]

In this study, the risk of hypertension in men was significantly associated with day–evening–night and night-time exposures to aircraft noise. The association with aircraft noise exposure during the day was not significant. This result was consistent with the one obtained in the HYENA study where the risk of hypertension related to night-time noise exposure tended to be more pronounced than for daytime aircraft noise exposure.[2] Differences in the relationship between cardiovascular outcomes and noise exposure regarding the use of different energy-based exposure indicators have been sparsely studied in community noise research. Most studies considered day–evening–night (L_{den}) or day–night (L_{dn}) or night-time (L_{night}) noise exposures.[5] Few studies considered different periods of the day ($L_{Aeq,\ 16\ hours}$).[5]

Table 3 Effects estimates of various aircraft noise indicators* on hypertension and BP in men

	Hypertension		Diastolic BP		Systolic BP	
Indicator of exposure	OR† (95% CI)	p Value	Increase in mm Hg‡ (95% CI)	p Value	Increase in mm Hg‡ (95% CI)	p Value
L_{den} (dB(A))	**1.48 (1.00 to 1.97)**	**0.04**	**1.86 (0.40 to 3.30)**	**0.01**	**2.37 (0.16 to 4.59)**	**0.04**
$L_{Aeq,\ 16\ hours}$ (dB(A))	1.34 (0.90 to 1.79)	0.10	**1.51 (0.11 to 2.92)**	**0.03**	**2.19 (0.05 to 4.34)**	**0.05**
L_{night} (dB(A))	**1.34 (1.00 to 1.97)**	**0.04**	**1.67 (0.34 to 3.00)**	**0.01**	**2.17 (0.13 to 4.19)**	**0.04**

Bold values are statistically significant p≤0.05.
*Per 10 dB(A) increase.
†Adjusted for age, gender, BMI, physical activity, alcohol consumption and professional activity.
‡Adjusted for age, gender, BMI, physical activity, alcohol consumption, professional activity and hypertensive medication.
BMI, body mass index; BP, blood pressure.

In this study, night-time and daytime exposures to aircraft noise at the place of residence were distinguished. Participants were more likely to be outside their home during the day than during the night, but no information was available about daytime aircraft noise exposure of the participants when outside their home, especially at their workplace. Misclassification of exposure might occur, but it is not likely that the exposure classification would depend on disease status. Therefore, such non-differential misclassification would have induced an appreciable downward bias, if there is a true association between aircraft noise exposure and hypertension. Furthermore, it was not possible to disentangle the effect on hypertension of night-time exposure at home and daytime exposure at work.

It is worth wondering whether energy-based indicators of exposure, such as L_{den}, L_{night} and $L_{Aeq,\ 16\ hours}$, were the most relevant indicators to describe the relationship between aircraft noise exposure and hypertension. In health studies, it is currently recommended to consider including event-related indicators like the number of noise events or the number of events exceeding a certain LAmax level (the maximum A-weighted sound pressure level), especially for the night period regarding the effects of aircraft noise on sleep quality. In addition to L_{den}, L_{night} and $L_{Aeq,\ 16\ hours}$, it would have been interesting to consider such noise indicators in this study to increase the impact of these results. Unfortunately, these indicators were not available in France.[26] However, in the next few months, such indicators will be available for a subsample of 100 participants in the longitudinal study for whom acoustic measurements at their place of residence have been carried out for 1 week.

The number of participants (n=1230) included in the study was small compared with the number of those included in other studies investigating the relation between aircraft noise and hypertension. Rosenlund *et al*[21] examined a possible relation between residential exposure to aircraft noise and hypertension among 266 residents in the vicinity of Stockholm Arlanda Airport, and 2693 inhabitants in other parts of Stockholm County. Eriksson *et al*[22] investigated the influence of aircraft noise on the incidence of hypertension in a cohort of 2754 men in four municipalities around Stockholm Arlanda Airport, followed between 1992–1994 and 2002–2004. The largest study until now, the HYENA study, included 4861 persons living near one of six major European airports.[2] It is likely that the association observed in this study would have become clearer among men if more participants were included in the study. The association might have become significant among women but it is very unlikely because, although the evidence is not fully consistent and the number of studies is limited, according to the literature, aircraft noise exposure seems to be associated with the risk of hypertension for men but not for women.

The participation rate in this study was similar to those in Germany, Italy and the UK in the HYENA study. This low participation rate could be a potential weakness of our study. However, according to a short questionnaire answered by those who refused to participate in the study and according to the distribution in aircraft noise exposure categories, non-responders were almost similar to the participants. On the other hand, since there were no questions on hypertension in the questionnaire addressed to those who refused to participate, the prevalence of hypertension was unknown among the non-responders.

The possible adverse effect of aircraft noise on hypertension could have led to a lower proportion of sensitive people among those living in the vicinity of airports. Little information to judge whether this has occurred is available. However, if it has occurred, this would have resulted in an underestimation of the association between aircraft noise exposure and hypertension in this study.

In total 315 participants were considered to be hypertensive because they had BP levels above the WHO cut-off points and 111 because they reported a diagnosis of hypertension by a physician in conjunction with use of antihypertensive medication in the interview questionnaire. Recall bias cannot be excluded for those who self-reported a diagnosis of hypertension by a physician. However, it is unlikely that people exposed to higher levels of aircraft noise would be more prone to recall a medical diagnosis of hypertension than others.

The fact that hypertension was defined based on only one visit BP measurement during the daytime was one of the limitations of this study, particularly since findings showed that it was night-time noise exposure that was significantly associated with hypertension in men.

No information was available on the date of hypertension diagnosis by a physician if it existed. Therefore, it was not possible to take into account a possible latency period between exposure and diagnosis of hypertension. Moreover, we cannot be sure that aircraft noise exposure preceded this diagnosis.

CONCLUSIONS

The DEBATS study is the first to investigate the relationship between long-term aircraft noise exposure and the risk of hypertension in men and in women near French airports. After adjustment for a lot of potential confounders, an exposure–response relationship was evidenced between the risk of hypertension and aircraft noise exposure at night for men only. These findings contribute to the overall evidence suggesting that aircraft noise exposure at night-time may increase the risk of hypertension in men. Hypertension is a well-known and established risk factor for cardiovascular disease. The association reported in the present study between aircraft noise and hypertension implies that aircraft noise might be a risk factor also for cardiovascular disease.

Acknowledgements The Airport Pollution Control Authority (ACNUSA) requested the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR) for carrying out this study. The authors would like to thank them for their confidence in them. They are grateful to all the participants in the study. They also thank Paris Airports and the French Civil Aviation Authority for providing noise exposure maps. They are also grateful to Inès Khati for her participation in the implementation of the study and to Jean-Louis Martin for his skilful revision of the manuscript.

Contributors A-SE and BL with JL and PC conceived and designed the study. A-SE and ML conducted the study. JL interpreted the aircraft noise data and PC interpreted the annoyance data. ML was involved in data extraction and preparation and carried out the statistical analyses, supervised by A-SE and BL. The analyses were interpreted by A-SE and ML with BL, JL and PC. A-SE drafted the initial report; all coauthors revised the report and approved the final version. A-SE is responsible for the overall content as the guarantor of this paper.

Funding This study was supported by funds from the French Ministry of Health, the French Ministry of Environment and the French Civil Aviation Authority.

Competing interests None declared.

Patient consent Obtained.

Ethics approval This study was approved by two national authorities in France, the French Advisory Committee for Data Processing in Health Research and the French National Commission for Data Protection and the Liberties.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. Babisch W. Updated exposure-response relationship between road traffic noise and coronary heart diseases: a meta-analysis. *Noise Health* 2014;16:1–9.
2. Jarup L, Babisch W, Houthuijs D, *et al*. Hypertension and Exposure to Noise Near Airports: the HYENA study. *Environ Health Perspect* 2008;116:329–33.
3. Floud S, Vigna-Taglianti F, Hansell A, *et al*. Medication use in relation to noise from aircraft and road traffic in six European countries: results of the HYENA study. *Occup Environ Med* 2011;68:518–24.
4. Franssen EA, van Wiechen CM, Nagelkerke NJ, *et al*. Aircraft noise around a large international airport and its impact on general health and medication use. *Occup Environ Med* 2004;61:405–13.
5. Babisch W, van Kamp Iv. Exposure-response relationship of the association between aircraft noise and the risk of hypertension. *Noise Health* 2009;11:161–8.
6. Eriksson C, Bluhm G, Hilding A, *et al*. Aircraft noise and incidence of hypertension —gender specific effects. *Environ Res* 2010;110:764–72.
7. Babisch W, Beule B, Schust M, *et al*. Traffic noise and risk of myocardial infarction. *Epidemiology* 2005;16:33–40.
8. Barregard L, Bonde E, Ohrström E. Risk of hypertension from exposure to road traffic noise in a population-based sample. *Occup Environ Med* 2009;66:410–15.
9. Leon Bluhm G, Berglind N, Nordling E, *et al*. Road traffic noise and hypertension. *Occup Environ Med* 2007;64:122–6.
10. Babisch W, Wölke G, Heinrich J, *et al*. Road traffic noise and hypertension—accounting for the location of rooms. *Environ Res* 2014;133:380–7.
11. Selander J, Nilsson ME, Bluhm G, *et al*. Long-term exposure to road traffic noise and myocardial infraction. *Epidemiology* 2009;20:272–9.
12. European Commission. Directive of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0049 (accessed 1 Dec 2014). Official Journal of the European Communities 2002;12–25.
13. Whitworth JA. World Health Organization, International Society of Hypertension Writing Group. 2003 World Health Organization (WHO)/International Society of Hypertension (ISH) statement on management of hypertension. *J Hypertens* 2003;21:1983–92.
14. He H, Boeker E, Dinges E. *Integrated Noise Model (INM) version 7.0 user's guide*. Washington USA: Federal Aviation Administration, Office of Environment and Energy, 2007.
15. Aéroports de Paris. Exposition au bruit des avions: Aéroport Paris-Charles de Gaulle —Compte rendu annuel. 2006. http://oissery.perso.neuf.fr/linked/exposition_au_bruit.pdf (accessed 19 Jul 2016).
16. Foret R, Bruyère JC, Yombo N. Etude empirique de la validité du Plan de Gêne Sonore de l'aéroport Lyon St Exupéry. Rapport d'étude du 12 septembre 2005. Chambre de commerce et d'industrie de Lyon, 2005.
17. Hastie T, Tibshirani R. *Generalized additive models*. London: Chapman and Hall/CRC Press, 1990.
18. Wood SN. *Generalized additive models: an introduction with R*. London: Chapman and Hall/CRC Press, 2006.
19. Godet-Thobie H, Vernay M, Noukpoape A, *et al*. Niveau tensionnel moyen et prévalence de l'hypertension artérielle chez les adultes de 18 à 74 ans, ENNS 2006-2007. *Bull Epidémiol Hebd* 2008;49-50:478–83.
20. Keuken MP, Moerman M, Zandveld P, *et al*. Total and size-resolved particle number and black carbon concentrations in urban areas near Schiphol Airport (the Netherlands). *Atmospheric Environ* 2015;104:132–42.
21. Rosenlund M, Berglind N, Pershagen G, *et al*. Increased prevalence of hypertension in a population exposed to aircraft noise. *Occup Environ Med* 2001;58:769–73.
22. Eriksson C, Rosenlund M, Pershagen G, *et al*. Aircraft noise and incidence of hypertension. *Epidemiology* 2007;18:716–21.
23. Jarup L, Dudley M, Babisch W, *et al*. Hypertension and Exposure to Noise Near Airports-The Hyena Study. *Epidemiology* 2007;18:S137.
24. Mosca L, Barrett-Connor E, Wenger NK. Sex/gender differences in cardiovascular disease prevention: what a difference a decade make. *Circulation* 2011;124:2145–54.
25. Dunlay SM, Roger VL. Gender differences in the pathophysiology, clinical presentation, and outcomes of ischemic heart failure. *Curr Heart Fail Rep* 2012;9:267–76.
26. Evrard AS, Khati I, Champelovier P, *et al*. Health effects of aircraft noise near three French airports: results from a pilot epidemiological study of the DEBATS study. In: Burroughs C, ed. *INTER-NOISE 2012, the 41st International Congress and Exposition on Noise Control Engineering*. New-York City, NY, USA: Institute of Noise Control Engineering (INCE), 2012:3888.

Does aircraft noise exposure increase the risk of hypertension in the population living near airports in France?

Anne-Sophie Evrard, Marie Lefèvre, Patricia Champelovier, Jacques Lambert and Bernard Laumon

Occup Environ Med 2017 74: 123-129 originally published online August 1, 2016
doi: 10.1136/oemed-2016-103648