Daytime and night-time aircraft noise and cardiovascular disease near Heathrow airport in London

Anna L. HANSELL[1,2]; Marta BLANGIARDO[1]; Lea FORTUNATO[1]; Sarah FLOUD[1]; Kees de HOOGH[1]; Daniela FECHT[1]; Rebecca E. GHOSH[1]; Helga E. LASZLO[1]; Clare PEARSON[1]; Linda BEALE[1]; Sean BEEVERS[3], John GULLIVER[1]; Nicky BEST[1]; Sylvia RICHARDSON[4], Paul ELLIOTT[1].

[1] Small Area Health Statistics Unit, MRC-PHE Centre for Environment and Health, Imperial College London, UK

[2] Public Health and Primary Care, Imperial College Healthcare NHS Trust, London, UK

[3] Environmental Research Group, MRC-PHE Centre for Environment and Health, Kings College London, UK

[4] MRC Biostatistics Unit, Cambridge, UK

ABSTRACT

Background. Few studies have investigated associations of aircraft noise with cardiovascular health. We investigated this in areas exposed to noise from London Heathrow airport.
Methods. A small area study was conducted in 12,110 census output areas covering 3.6 million residents. Risks for hospital admissions and mortality in 2001-05 were assessed in relation to aircraft noise in 2001, adjusted for relevant confounders. Night (L_{night}) and daytime ($L_{Aeq,16h}$) aircraft noise were assessed separately.
Results. Higher aircraft noise was associated with higher relative risks for hospital admissions and mortality from stroke, coronary heart disease (CHD) and cardiovascular disease. Risk estimates were higher for night-time than daytime noise. Adjusted risks were highest for stroke, with RR 1.29 [95% CI 1.14 to 1.46] for L_{night} and RR 1.08 [95% CI 1.02 to 1.14] for $L_{Aeq,16h}$ for >55dB vs. <50dB. All linear dose-response relationships were statistically significant for hospital admissions but not for mortality, except for CHD and $L_{Aeq,16h}$.
Discussion. This research attracted a high level of policy interest. However, the impact of this and other recent papers on policy decisions such as increased airport capacity in England is currently unclear. Priority areas for follow-up health research into aircraft noise need to be considered.

Keywords: Aircraft noise, health, cardiovascular disease
I-INCE Classification of Subjects Number(s): 62.5
(http://www.inceusa.org/links/Subj%20Class%20-%20Formatted.pdf .)

1. INTRODUCTION

Although the literature on population annoyance associated with aircraft noise is extensive (1,2) little research has been conducted on the potential effects of aircraft noise on cardiovascular health (2). Most studies of the health effects associated with aircraft noise have focused on blood pressure and the risk of hypertension (3–8). The few reports of aircraft noise and risk of stroke, coronary heart disease, or cardiovascular disease are inconsistent (9–11), partly reflecting reduced statistical power

Heathrow airport, situated in a densely populated area in west London, is one of the busiest airports in the world. Reports have shown an association between aircraft noise, especially at night, and hypertension (3), acute increases in blood pressure (7), and self-reported cardiovascular disease (11) in the population living near airports, including Heathrow. We investigated the risks of stroke, coronary

[1] a.hansell@imperial.ac.uk

heart disease, and cardiovascular disease hospital admissions and mortality in areas exposed to aircraft noise near Heathrow airport.

2. METHODS

2.1 Study area

The study area comprised twelve London boroughs and nine districts west of London that were exposed to aircraft noise related to Heathrow airport. Exposure wad defined as being partly or wholly within the 2001 50 dB noise contour for Heathrow aircraft during the daytime (LAeq,16h) supplied by the Civil Aviation Authority. Additionally, we had confounder data for particulate air pollution and road traffic noise for the twelve London boroughs (data for districts outside London were not readily comparable with the data available for London). We defined neighbourhoods (small areas) by using the national census geographical units, which are census output areas and super output areas (an aggregate of on average five census output areas). The study area comprised 12,110 census output areas (average 297 inhabitants, area 0.13 km2) and 2378 super output areas (1510 inhabitants, area 0.65 km2). For hospital admissions we used the census output area as the unit of analysis. For mortality we used the super output area as the numbers of deaths were insufficient for meaningful analyses at census output area level. We used Office for National Statistics annual mid-year population estimates by age and sex for 2001-05 at London borough or district level, which we then disaggregated to census output areas and super output areas using the UK 2001 census age-sex distribution.

2.2 Aircraft noise data

Aircraft noise data were obtained from the Civil Aviation Authority on 10 m × 10 m grids. The noise data had been modelled using the UK Civil Aircraft Noise Contour Model ANCON, which uses information on flight paths of arriving and departing aircraft along with factors such as height, speed, and engine power to derive noise at ground level (12). We calculated population weighted annual average noise levels for daytime and night time aircraft noise for census output areas and super output areas.

We grouped daytime aircraft noise and road noise into six categories from ≤51 to >63 dB in increments of 3 dB, Night time aircraft noise affected fewer areas and 5 dB categories (≤50, >50-55, and >55 dB) were used.

2.3 Health data

For the study area, 2001-05, we extracted data on hospital admissions (main reason for admission, first episode of stay in a given year) using Hospital Episode Statistics (HES) from the Health and Social Care Information Centre and deaths (by underlying cause) from Office for National Statistics and Department of Health data held by the UK Small Area Health Statistics Unit at Imperial College London. Data were obtained for stroke (ICD-10 codes I61, I63-I64, international classification of diseases, 10th revision), coronary heart disease (ICD-10 I20-I25), and cardiovascular disease (ICD-10 Chapter I) and then linked these by postcode (average 23 households) to census output area and super output area.

2.4 Confounder data

We included ethnicity, deprivation, and a smoking proxy at census output area and super output area level as potential confounders. Area level ethnic composition and deprivation from the 2001 census were obtained from the Office for National Statistics. For the two major ethnic groups in London, we categorised areas by South Asian ethnicity (census term “Asian or Asian British,” for which we included only “Indian,” “Pakistani,” and “Bangladeshi”) and black ethnicity (census term “Black or Black British,” which includes “Black Caribbean,” “Black African,” and “Other Black”). We used the following cut points: the national average (%) for England and Wales at census output area level (4% for South Asian, 2% for black ethnicity), double the national average (8%, 4%), and 50% South Asian or black ethnicity—areas where these comprised the majority ethnic group. This gave us four categories for each ethnicity, where the reference categories were less than or equal to the national average (%) for that ethnic group (≤4% for South Asian and ≤2% for black ethnicity). The deprivation score used was Carstairs index (13) categorised in fifths. Since data on individual smoking or smoking prevalence were not available we used a proxy measure for area level smoking. The proxy measure used was smoothed lung cancer mortality (ICD-10 codes C33-C34) relative risk estimates (2005) for census output areas and super output areas.

2.5 Statistical analysis

A Poisson regression, with an additional random effect term to account for over-dispersion and residual heterogeneity, was used to conduct a small area analysis of aircraft noise and the three cardiovascular outcomes. The potential confounders adjusted for at area level (census output area or super output area) were: age, sex, South Asian and black ethnicity, deprivation, and a smoking proxy (lung cancer mortality risk).

3. RESULTS

3.1 Descriptive analyses

The study area population (2001 census) was 3.6 million. During 2001-05, 189,226 first episodes of hospital stay in a given year for cardiovascular disease (16,983 stroke, 64,448 coronary heart disease) and 48,347 cardiovascular disease related deaths (9803 stroke, 22,613 coronary heart disease) occurred in the study area.

3.2 Hospital admissions

For stroke, coronary heart disease, and cardiovascular disease hospitalizations the pattern (Figure 1) was of increasing risk of admissions with increasing aircraft noise, and all linear tests for trend were statistically significant ($P<0.001$ to $P<0.05$). The risk of coronary heart disease in particular, and to a lesser extent cardiovascular disease, was noticeably reduced by adjustment for multiple confounders, in particular South Asian ethnicity. In multiple adjustment models, for daytime aircraft noise (>63 dB v ≤51 dB) the relative risk for stroke was 1.24 (1.08 to 1.43), for coronary heart disease was 1.21 (1.12 to 1.31), and for cardiovascular disease was 1.14 (1.08 to 1.20). Corresponding relative risks for night time noise (>55 dB v ≤50 dB) were 1.29 (1.14 to 1.46), 1.12 (1.04 to 1.20), and 1.09 (1.04 to 1.14).

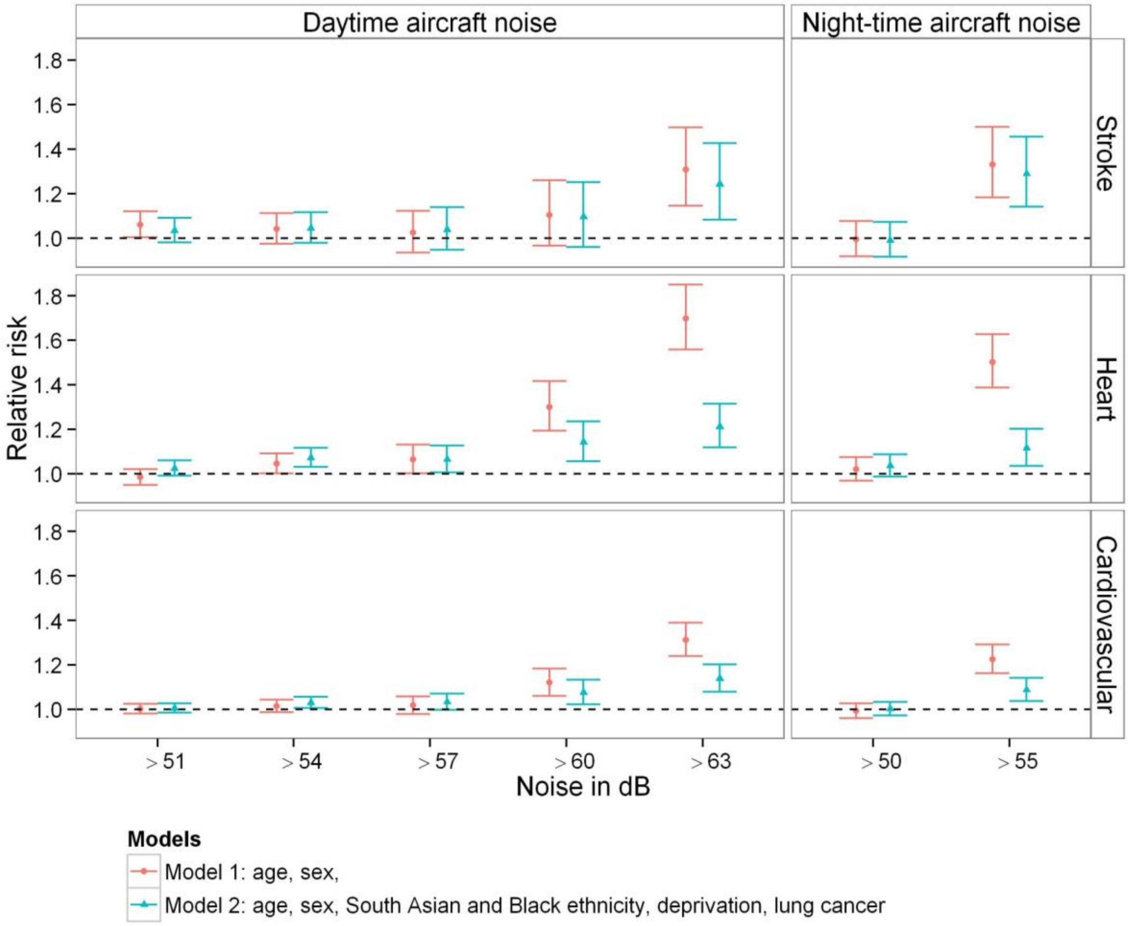

Figure 1 –Relative risks (95% confidence intervals) for associations between hospital admissions for stroke, coronary heart disease, and cardiovascular disease in 2001-05 and annual population weighted average daytime aircraft noise (relative to ≤51 dB) and night time aircraft noise (relative to ≤50 dB) in 2001, in census output areas

3.3 Mortality

The relative risks of mortality were numerically similar to those for hospital admissions at the higher noise levels, although confidence intervals were wider, reflecting the smaller numbers of events. The relative risks of mortality for night time aircraft noise (>55 dB v ≤50 dB) were 1.23 (1.02 to 1.49), 1.11 (0.99 to 1.24), and 1.14 (1.03 to 1.26) (Table 1). Tests for linear trend across noise categories in the fully adjusted models were significant (P<0.05) for daytime noise and coronary heart disease but not for stroke or cardiovascular disease, nor night time noise.

3.4 Daytime vs. night-time noise

Using the same 5dB categories for daytime noise exposure suggested higher relative risks for night-time noise (Table 1). However, daytime and night-time noise were very highly correlated (r=0.98).

Table 1: Relative risks (RR) and 95% Confidence Intervals for associations between stroke, coronary heart disease (CHD) and cardiovascular disease (CVD) and hospital admissions and mortality (2001-2005) and 2001 annual population-weighted average daytime noise (5dB categories) and night-time aircraft noise, including random effects

		RR [95% CI]	
		Adjusted for age and sex ethnicity, deprivation, lung cancer	
Outcome	Exposure category	Daytime aircraft noise in dB (5 dB categories)	Night-time aircraft noise in dB (5 dB categories)
Hospital admissions			
Stroke	≤ 50	1	1
	>50-55	1.04 [0.99;1.08]	0.99 [0.92;1.07]
	>55	1.08 [1.02;1.14]	1.29 [1.14;1.46]
	linear trend p-value	0.005	0.020
CHD	≤ 50	1	1
	>50-55	1.02 [0.99;1.04]	1.04 [0.99;1.09]
	>55	1.09 [1.05;1.13]	1.12 [1.04;1.20]
	linear trend p-value	0.000	0.004
CVD	≤ 50	1	1
	>50-55	1.00 [0.99;1.02]	1.00 [0.97;1.03]
	>55	1.05 [1.03;1.07]	1.09 [1.04;1.14]
	linear trend p-value	0.000	0.024
Mortality			
Stroke	≤ 50	1	1
	>50-55	1.10 [1.02;1.17]	0.92 [0.81;1.05]
	>55	1.02 [0.93;1.12]	1.23 [1.02;1.49]
	linear trend p-value	0.096	0.569
CHD	≤ 50	1	1
	>50-55	1.02 [0.98;1.06]	0.95 [0.88;1.02]
	>55	1.05 [0.99;1.11]	1.11 [0.99;1.24]
	linear trend p-value	0.062	0.796
CVD	≤ 50	1	1
	>50-55	1.03 [1.00;1.07]	0.96 [0.90;1.03]
	>55	1.04 [0.99;1.09]	1.14 [1.03;1.26]
	linear trend p-value	0.044	0.347

4. DISCUSSION

4.1 Main findings

In this small area study covering a population of 3.6 million people living near Heathrow airport in London, we identified significant excess risks of hospital admissions and mortality from stroke, coronary heart disease, and cardiovascular disease, especially among the 2% of the population affected by the highest levels of daytime and night time aircraft noise.

4.2 Night-time vs. daytime noise

We were unable to distinguish between night time and daytime noise as they were highly correlated and so their effects could not be differentiated. However, when using the same 5dB increments for both daytime and night-time exposure higher relative risks were seen for night-time noise exposure for both hospital admissions and mortality. More research is needed to determine if night time noise that disrupts sleep may be a mechanism underlying observed associations.

4.3 Strengths and weaknesses of the study

Strengths of this study include the large general population sample, inclusion of both incident events (hospital admissions) and mortality, and wide range of aircraft noise levels, providing sufficient statistical power to detect modest associations. Limitations include inability to adjust for confounders at individual level.

Admissions for coronary heart disease and to a lesser extent for cardiovascular disease were particularly affected by adjustment for South Asian ethnicity, which itself is strongly associated with risk of coronary heart disease (14); so these risk estimates should be interpreted cautiously. We restricted our hospital admission analyses to the first admission within one calendar year; as we did not link across years it is possible that some may be readmissions if they occurred in different calendar years. However, point estimates at higher noise levels were similar for mortality and hospital admissions, making it less likely that this was an important source of bias.

4.4 Study impact on policy

The paper was published in the BMJ in October 2013, together with a study looking at 89 US airports (15). Airports and health were the lead story on the BMJ paper edition that week and the BMJ website. The paper received a high degree of coverage in the press and policy interest. A press conference was held immediately prior to publication. The study was covered by both national and international press – the latter ranging from The Times of London, the Mongolian Daily and (on the front page of) the Sydney Morning Herald. Paper authors were involved in 15 local, national and international radio interviews (including a Melbourne drivetime programme) and interviews with BBC, ITV London and Sky news, the Islam channel, and China Central TV.

A governmental department briefing was organized prior to the study publication including up to the Prime Minister's office – the issue of a third runway at Heathrow was a campaigning issue for some London Members of Parliament at the last election and a decision was made on the first day of the incoming (current) coalition government to postpone any decision on a third runway at Heathrow pending a report from a government commission. The present study featured as a question in Prime Minister's Questions on the day of publication (below) and in parliamentary questions on three other occasions.

HANSARD REPORT of SAHSU Heathrow study at Prime Minister's questions

Mr John Randall (Uxbridge and South Ruislip) (Con): May I draw my right hon. Friend's attention to the recent report by Imperial college about the detrimental effects on health of aircraft noise? Will he make sure that when the Government look at and decide on the Davies commission's report on aviation in the south-east, health and environmental considerations are paramount?

The Prime Minister: My right hon. Friend has not had the chance to speak from the Back

> *Benches in the way that he just has, and I look forward to hearing many other contributions from him, he brings a huge amount to this House. He is absolutely right to raise the issue of environmental noise, and I can tell him that it will be included in the report by Howard Davies and he will be making a speech about the issue soon.*

The paper was extensively reviewed in a recent UK Civil Aviation Authority publication commissioned by the Department of Transport (16). The report reviewed recent developments since January 2013 in aircraft noise, sleep disturbance and health effects. The interim report from the Airports (Davies) commission (17), which short-lists Gatwick and Heathrow airports to be considered for an additional runway, states that "aircraft noise causes considerable annoyance to the communities it affects and there is a growing body of evidence regarding its impacts on human health" and has committed to include in the final report "the impacts of airports on the quality of life for people living and working near airports, such as the impacts of aircraft noise." The final report of the Davies commission is expected in summer 2015.

5. CONCLUSIONS

Our results suggest that high levels of aircraft noise are associated with an increased risk of stroke coronary heart disease, and cardiovascular disease. As well as the possibility of causal associations, alternative explanations should be considered. These include the potential for incompletely controlled confounding and ecological bias, as we did not have access to individual level confounder data such as ethnicity and smoking. Further work to understand better the possible health effects of aircraft noise is needed, including studies clarifying the relative importance of night time compared with daytime noise. Priority areas for follow-up health research into aircraft noise need to be considered.

This research has attracted a high level of policy interest and will be considered by the commission advising on potential increased airport capacity in the UK.

ACKNOWLEDGEMENTS

We dedicate this paper to Lars Jarup who helped initiate this project and passed away in 2010. We thank Peter Hambly, Margaret Douglass, Eric Johnson, Kayoung Lee, and David Morley for technical support and the advisory group members: Tim Williams, Yvette Bosworth (Defra), Stephen Turner (Bureau Veritas/Defra), and Nigel Jones (Extrium) who provided traffic noise data, and Darren Rhodes and Kay Jones (Civil Aviation Authority) who provided aircraft noise data.

The article is adapted from that originally published in the BMJ at http://www.bmj.com/content/347/bmj.f5432 distributed under a Creative Commons Attribution Non Commercial (CC BY-NC 3.0) license. No commercial reuse: See rights and reprints http://www.bmj.com/permissions .

The work of the UK Small Area Health Statistics Unit is funded by Public Health England as part of the MRC-PHE Centre for Environment and Health, funded also by the UK Medical Research Council. Support was received from the European Network for Noise and Health (ENNAH), EU FP7 grant No 226442. PE acknowledges support from the National Institute for Health Research (NIHR) Biomedical Research Centre at Imperial College Healthcare NHS Trust and Imperial College London. PE is an NIHR senior investigator. The funders had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the article; and in the decision to submit the article for publication. The advisory group provided advice on methodology but was not involved in the analyses, interpretation of results, or writing of the paper. The views expressed are those of the authors and not necessarily those of the NHS, NIHR, or Department of Health.

Hospital Episode Statistics data are copyright © 2013, Re-used with the permission of the Health and Social Care Information Centre. All rights reserved.

The mortality and population data were supplied by the Office for National Statistics (ONS), derived from the national mortality registrations and the Census.

References:

1. Miedema HM, Vos H. Exposure-response relationships for transportation noise. J Acoust Soc Am. 1998;104(September 1997):3432–45.

2. World Health Organisation. WHO | Burden of disease from environmental noise - Quantification of healthy life years lost in Europe [Internet]. World Health Organization; 2011. Available from: http://www.who.int/quantifying_ehimpacts/publications/e94888/en/

3. Jarup L, Babisch W, Houthuijs D, Pershagen G, Katsouyanni K, Cadum E, et al. Hypertension and exposure to noise near airports: the HYENA study. Environ Health Perspect. 2008;116:329–33.

4. Eriksson C, Rosenlund M, Pershagen G, Hilding A, Ostenson C-G, Bluhm G. Aircraft noise and incidence of hypertension. Epidemiology. 2007;18:716–21.

5. Eriksson C, Bluhm G, Hilding A, Östenson CG, Pershagen G. Aircraft noise and incidence of hypertension-Gender specific effects. Environ Res. 2010;110:764–72.

6. Rosenlund M, Berglind N, Pershagen G, Järup L, Bluhm G. Increased prevalence of hypertension in a population exposed to aircraft noise. Occup Environ Med. 2001;58:769–73.

7. Haralabidis AS, Dimakopoulou K, Vigna-Taglianti F, Giampaolo M, Borgini A, Dudley ML, et al. Acute effects of night-time noise exposure on blood pressure in populations living near airports. Eur Heart J. 2008;29:658–64.

8. Babisch W, Kamp I van. Exposure-response relationship of the association between aircraft noise and the risk of hypertension. Noise Health [Internet]. Medknow Publications; 2009 Jan 1 [cited 2014 Aug 14];11(44):161–8. Available from: http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2009;volume=11;issue=44;spage=161;epage=168;aulast=Babisch

9. Huss A, Spoerri A, Egger M, Röösli M. Aircraft noise, air pollution, and mortality from myocardial infarction. Epidemiology [Internet]. 2010 Nov [cited 2014 Aug 14];21(6):829–36. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20881600

10. Sørensen M, Hvidberg M, Andersen ZJ, Nordsborg RB, Lillelund KG, Jakobsen J, et al. Road traffic noise and stroke: a prospective cohort study. Eur Heart J [Internet]. 2011 Mar 25 [cited 2014 Aug 14];32(6):737–44. Available from: http://eurheartj.oxfordjournals.org/content/early/2011/01/08/eurheartj.ehq466.full

11. Floud S, Blangiardo M, Clark C, de Hoogh K, Babisch W, Houthuijs D, et al. Exposure to aircraft and road traffic noise and associations with heart disease and stroke in six European countries: a cross-sectional study. Environ Health [Internet]. 2013 Jan [cited 2014 Jul 14];12(1):89. Available from: http://www.ehjournal.net/content/12/1/89

12. Ollerhead J, Rhodes D, Viinikainen M, Monkman D, Woodley A. The UK Civil Aircraft Noise Contour Model ANCON : Improvements in Version 2 (R & D REPORT 9842). Transport. 1999.

13. Carstairs V, Morris R. Deprivation and health in Scotland. Heal Bull. Aberdeen; 1990;48(4):162–75.

14. Balarajan R. Ethnic differences in mortality from ischaemic heart disease and cerebrovascular disease in England and Wales. BMJ. 1991;302:560–4.

15. Correia AW, Peters JL, Levy JI, Melly S, Dominici F. Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: multi-airport retrospective study. BMJ [Internet]. 2013 Jan 8 [cited 2014 Aug 15];347(oct08_3):f5561. Available from: http://www.bmj.com/content/347/bmj.f5561

16. Civil Aviation Authority. Aircraft noise , sleep disturbance and health effects [Internet]. 2014. Available from: http://www.caa.co.uk/docs/33/CAP 1164_Aircraft noise_and_health.pdf

17. Airports Commission. Airports Commission: Interim Report [Internet]. 2013. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf