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Noise exposure and children's blood pressure and heart rate: the RANCH project

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Abstract

Background

Conclusions that can be drawn from earlier studies on noise and children's blood pressure are limited due to inconsistent results, methodological problems, and the focus on school noise exposure.

Objectives

To investigate the effects of aircraft and road traffic noise exposure on children's blood pressure and heart rate.

Methods

Participants were 1283 children (age 9–11 years) attending 62 primary schools around two European airports. Data were pooled and analysed using multilevel modelling. Adjustments were made for a range of socioeconomic and lifestyle factors.

Results

After pooling the data, aircraft noise exposure at school was related to a statistically non-significant increase in blood pressure and heart rate. Aircraft noise exposure at home was related to a statistically significant increase in blood pressure. Aircraft noise exposure during the night at home was positively and significantly associated with blood pressure. The findings differed between the Dutch and British samples. Negative associations were found between road traffic noise exposure and blood pressure, which cannot be explained.

Conclusion

On the basis of this study and previous scientific literature, no unequivocal conclusions can be drawn about the relationship between community noise and children's blood pressure.

Keywords: aircraft noise, blood pressure, road traffic noise, heart rate

Road and aircraft noise are two of the most important sources of community noise.[1] It has been estimated that approximately 30% of the European Union's population is exposed to levels of road traffic noise of more than 55 dB(A); 20% of the European population experience noise levels that are considered unacceptable.[2] Long term noise exposure is associated with a number of effects on health and wellbeing. These include community responses such as annoyance, sleep disturbance, disturbance of daily activities, and physiological responses such as hearing loss, hypertension, and ischaemic heart disease.[2]

This paper focuses on blood pressure changes in children. From a public health perspective, blood pressure elevations at the population level are undesirable.[3] In relation to noise, blood pressure elevations are regarded as a non-specific response. However, they are typically associated with stress which is hypothesised to arise either as a consequence of activation of the autonomic nervous system and the endocrine system or as a consequence of the appraisal of noise.[4,5] With the preponderant influence of lifestyle and genetic predisposition, it is difficult to gain insight into the contribution of noise to cardiovascular disease. This is probably one of the reasons why conclusions from earlier studies investigating the effects of noise exposure on children's blood pressure are limited and inconsistent. Secondly, a number of methodological problems emerge from these earlier studies (e.g. small differences in noise levels between the exposure groups, potential selection bias, a lack of control for socioeconomic status factors, differences in insulation, and parental history of high blood pressure).[3,4,5] Thirdly, most studies usually only focus on exposure at school when investigating the effects of noise exposure on children. It is questionable whether the health effects could be exclusively attributed to the noise exposure in school. The effect of night-time exposure has been hardly investigated in children.[6] This is an important gap in the research, because time use studies not only show that children spent a lot of time in and around their home, but also that children spend a large part of their time sleeping.[7,8] Chronic night-time noise exposure might disturb the excretion of stress hormones (such as cortisol), which affects children's health.[9]

To investigate the possible association between noise exposure and children's blood pressure and heart rate, we collected data from children living around Heathrow Airport and Schiphol Airport, gathered in the framework of the RANCH project. The aim of this project was to investigate the effects of aircraft and road traffic noise exposure at school on children's cognition and health.[10] In a later stage of the project the home noise exposure levels also became available.

Methods

Selection and recruitment

Children aged 9–10 years were recruited from primary schools in areas around Heathrow Airport and Schiphol Airport. Schools were selected according to the modelled noise exposure due to both aircraft and road traffic of the school area (expressed as $L_{Aeq,\ 7–23hr}$), and were matched on indicators of socioeconomic status (SES) and ethnicity. Schools for children with special needs were excluded. Since degrees of achievement can appreciably differ between school types in the UK, we excluded non-state schools in the UK from our study; in the Netherlands the degrees of achievement do not differ between school types. Furthermore, we excluded schools with the presence of a dominant noise source other than aircraft or road traffic noise, or at which insulation against noise was above a certain threshold; in the Netherlands all schools with high aircraft noise levels were highly insulated.

Of 118 primary schools available in the British study area, 30 were invited to participate and all but one agreed. In the Netherlands, of 366 available schools in the selected areas, 77 schools were invited to participate, and 33 agreed. The parents or carers of 2179 children were approached through the schools by letter; 2012 children had permission to take part. In the Netherlands all the children who had permission to take part and who were available on the day of testing had their blood pressure measured (n=730); in the United Kingdom every second participating child was selected from the class list for blood pressure measurement (n=553).

Noise exposure assessment using modelled data

Noise exposure was assessed for each child by linking home and/or school addresses to modelled equivalent aircraft and road traffic noise levels. These predict the average outdoor noise exposure during a specified time interval.

In both centres, aircraft noise levels ($L_{Aeq,\ 7–23hr,}$ and $L_{Aeq,\ 23–7hr}$) were obtained from nationally available noise contours for both the home and school situation. In the Netherlands, modelled aircraft noise levels for the year 2001 were obtained from the Dutch National Aerospace Laboratory (NLR).[11] In the United Kingdom, modelled aircraft noise levels were based on the 16 hour outdoor LAeq contours provided by the Civil Aviation Authority (CAA) for a three month period (July–September) for the year 2000.

In both centres, road traffic noise levels ($L_{Aeq,\ 7–23hr}$) were obtained for the school situation. Road traffic noise levels ($L_{Aeq,\ 7–23hr}$) for the home situation were only available for the Dutch sample. For the calculation of road traffic noise levels in the Netherlands, national standard methods were adopted to obtain grids with resolutions of 25×25 m.[11] In the United Kingdom, road traffic noise levels were calculated by means of the UK standard CRTN noise prediction method, using a combination of information including proximity to motorways, A-roads, B-roads, and traffic flow data.[12]

Blood pressure

Blood pressure measurements were taken in the afternoon in a quiet room in the school building using automatic blood pressure meters (OMRON 711, OMNILABO International BV). Cuff sizes of either 15–22 (small) or 22–32 cm (normal) were used. The cuff was placed on the right arm. While the child was seated and after an initial period of five minutes rest, systolic and diastolic blood pressure and heart rate were measured three times with 1–2 minute intervals by researchers trained according to a standard protocol. Children were not allowed to talk during the measurement session. Body height and weight were measured without shoes or heavy clothing. At the beginning of each session, room temperature was assessed. In the data analysis the mean value of the three blood pressure measurements was used.

Parent questionnaire

Children were given a questionnaire to take home for their mother (preferably), or other carer to complete. The questionnaire provided information on potential confounding factors (e.g. socioeconomic status, birth weight, country of birth, and parental history of high blood pressure); 84.8% of the parents (n=1175) returned the questionnaire.

Statistical analysis

Before running the analyses, the residuals were checked for outliers. Missing values were few, except for parental hypertension (11%) and cuff size (9%). Because small cuffs were used 95% of the time, the missing cuff sizes in the UK sample were imputed as small. To produce persistent effects, noise may have to be present for a certain length of time. Therefore, only those children who attended their present school for at least one year were included in the analyses.

To take into account the hierarchical data structure (children grouped within school), multilevel modelling was applied, using the MIXED procedure of SAS version 8.1. A two level random effects model was used. Country was included as a fixed effect. For the school situation the following two models were run: a model including noise exposure ($L_{Aeq,\ 7–23hr}$) at school, age (years), sex, ponderosity (weight/height^3), school glazing (single/double/mixed/triple), and country (UK/NL); the second model equals the first model with the addition of indicators for socioeconomic status (crowding, home ownership, employment, and mother's education), ethnicity (white/non-white), cuff-size (small, normal), room temperature (°C), birth weight (<2500 g/⩾2500 g), (self-reported) parental high blood pressure (yes/no), prematurity (born before week 36), double glazing at home, and the other school noise exposure ($L_{Aeq,\ 7–23hr}$) source. For the home situation the following two models were run: a model including noise exposure at home ($L_{Aeq,\ 7–23hr}$ or $L_{Aeq,\ 23–7hr}$), age (years), sex, ponderosity (weight/height^3), double glazing at home (yes/no), and country (UK/NL); the second model equals the first model with the addition of indicators for socioeconomic status (crowding, home ownership, employment, and mother's education), ethnicity (white/non-white), cuff-size (small, normal), room temperature (°C), birth weight (<2500 g/⩾2500 g), (self-reported) parental hypertension (yes/no), and prematurity (born before week 36).

The variables included in the models were chosen according to the literature. Furthermore, variables were retained in the main analysis if an analysis of covariance showed a significant relation between the confounding factor and aircraft noise exposure and/or road traffic noise exposure and/or blood pressure. As a result of these analyses, coefficients (B) and standard errors (SE) are presented, indicating the change in blood pressure per dB(A) increase. These were estimated under restricted maximum likelihood estimation. Ninety five per cent confidence intervals (95% CI) were calculated by means of the estimated standard errors. Statistical significance was tested under full maximum likelihood estimation, using a χ^2 test of deviance. Heterogeneity between the countries was tested in the models on the pooled data by examining the interaction between country and noise exposure.

In order to compare the results of our study systematically with the results of five other recent studies that investigated the association between community noise and children's blood pressure, we calculated the blood pressure change (mmHg) per noise level increase and its variance for both systolic and diastolic blood pressure.[13,14,15,16,17,18,19] To this end we evaluated the studies systematically and extracted average blood pressure values that were presented in these studies and their noise levels. This was done in the same way as was done by Van Kempen *et al*.[3]

In the UK, ethical approval for the study was given by the East London and the City Local Research Ethics Committee, East Berkshire Local Research Ethics Committee, Hillingdon Local Research Ethics Committee, and the Hounslow District Research Ethics Committees. In the Netherlands, the study was approved by the Medical Ethics Committee of TNO.

Results

General characteristics

A total of 853 children were eligible for data analysis (see also fig 1). Table 1 presents the general characteristics of these children and the schools they attended. It shows that: (i) the UK sample contains fewer employed parents and fewer homeowners; (ii) children in the UK sample had a lower average birth weight and a higher prevalence of prematurity than the Dutch sample; (iii) on average the children of the UK sample have higher blood pressure than the children of the Dutch sample; and (iv) the UK sample contains relatively more non-white children than the Dutch sample.

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Figure 1 Flowchart indicating what has happened with the children that were invited to participate in RANCH. BP, blood pressure.

Table 1 General characteristics of the children included in the analysis and the schools they attend

Characteristic	Overall (n=853) Mean (SD)	Range	%	UK sample (n=351) Mean (SD)	Range	%	NL sample (n=502) Mean (SD)	Range	%
Number of participating schools	62			29			33		
Girls			51.5			53.3			50.2
Age (yr)	10.4 (0.5)			10.3 (0.3)			10.5 (0.6)		
Blood pressure measurements									
Systolic blood pressure (mmHg)	106.8 (10.4)			108.9 (9.7)			105.4 (10.6)		
Diastolic blood pressure (mmHg)	66.2 (8.3)			67.1 (7.9)			65.6 (8.4)		
Pulse (beats/min)	83.9 (11.9)			89.4 (11.5)			80.1 (10.7)		
% small cuff size used			90.4			95.2			87.1
Room temperature (°C)	22.4 (2.0)			23.1 (1.6)			22.0 (2.1)		
Biometrics									
Ponderosity (kg/m^3)	12.61 (2.04)			13.25 (2.21)			12.17 (1.77)		
Birth weight <2500 g			7.7			9.1			6.8
Premature¶			7.3			12.5			3.6
Modelled noise exposure levels in dB(A)									
Aircraft noise									
At school ($L_{Aeq,\ 7–23hr}$)	58	(34–68)		60	(34–68)		54	(36–63)	
At home ($L_{Aeq,\ 7–23hr}$)	51.0	(34–73)		53.4	(34–73)		49.3	(35–65)	
At home ($L_{Aeq,\ 23–7hr}$)	40.9	(28–67)		43.2	(28–67)		39.2	(29–57)	
Road traffic noise									
At school ($L_{Aeq,\ 7–23hr}$)	56	(34–67)		57	(37–67)		55	(34–62)	

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*Ethnicity of the child's mother was used as a proxy for the child's ethnicity.

†Crowding is an objective measure of the number of people per room in a dwelling. In the UK, the official definition of crowded from the census is more than 1.5 people per room per dwelling; in the Netherlands crowding is defined as the number of people being smaller/equal to the number of rooms in a dwelling.

‡This is a measure of the highest employment status in the child's household. In the UK, employed means that the parent is working full time or part time; in the Netherlands, employed means that the parent does paid work for at least 19 hours a week.

§Mother's education was measured using a ranked index of standard qualifications in each country. A relative index was then calculated for this variable, so that comparisons could be made between the different measures in each country (index ranges from 0–1, with higher number indicating low educational attainment).

¶Prematurity means that the child was born before week 36 of the pregnancy.

**Parental high blood pressure indicated whether one or both parents had high blood pressure and/or used antihypertensive drugs either currently or in the past.

††School buildings containing double and single glazed windows.

n=sample size; SD=standard deviation; NA=not available.

Exposure characterisation

In the UK sample high correlations between home and school aircraft noise levels ($L_{Aeq,\ 7–23hr}$) ($L_{Aeq,\ 7–23hr}$) were found ($r \sim 0.9$). High correlations were also found in the Dutch sample between the aircraft noise level at school ($L_{Aeq,\ 7–23hr}$) and the aircraft noise level at home ($r > 0.7$). The correlation between home and school road traffic noise levels ($L_{Aeq,\ 7–23hr}$) in the Dutch sample was moderate ($r \sim 0.6$).

Aircraft noise exposure

The results of multilevel analysis (table 2) show that after pooling the data, aircraft noise exposure at school and at home was related to a statistically significant increase in systolic blood pressure. Only the effect of aircraft noise exposure at home remained when the model was further adjusted for socioeconomic status, ethnicity, cuff size, room temperature, birth weight, parental hypertension, and prematurity. Strong associations with systolic blood pressure were found for ponderosity, centre, parental high blood pressure, and cuff size.

Table 2 The fully adjusted multilevel models* on the pooled sample for noise exposure and systolic blood pressure (only children visiting their school for at least 1 year) (n=853)

	At school		At home	
	Model 1	Model 2	Model 1	Model 2
Fixed coefficients	B (95% CI)†	B (95% CI)†	B (95% CI)†	B (95% CI)†
Intercept	78.01 (60.58–95.43)	75.01 (55.14–94.87)	74.74 (58.39–91.08)	69.03 (49.23–88.83)
Noise exposure ($L_{Aeq\ 7–23hr}$) in dB(A)				
Air traffic noise at school	0.11 (0.00–0.21)‡	0.08 (−0.02, 0.18)		
Road traffic noise at school		−0.11 (−0.21, 0.00)‡		
Aircraft noise at home		–	0.14 (0.04–0.24)‡	0.10 (0.00–0.20)‡
UK	1.94 (0.04–3.84)‡	1.95 (−0.01, 3.91)‡	1.55 (−0.25–3.35)	1.68 (−0.33–3.68)
Age (years)	0.45 (−1.05–1.95)	1.08 (−0.40, 2.55)	0.47 (−1.01–1.94)	0.90 (−0.57–2.37)
Boys	0.50 (−0.81–1.80)	0.52 (−0.76, 1.81)	0.50 (−0.81–1.80)	0.55 (−0.74–1.84)
Ponderosity (kg/m^3)	1.54 (1.21–1.88)‡	2.06 (1.70, 2.43)‡	1.55 (1.22–1.89)‡	2.05 (1.70–2.40‡
School glazing				
Single	−1.85 (−5.78–2.09)	−0.86 (−4.54 , 2.81)		−0.53 (−4.25–3.19)
Single and double	−3.32 (−9.38–2.73)	−2.03 (−7.63, 3.58)		−1.68 (−7.38–4.02)
Double	−1.99 (−5.92–1.94)	−1.58 (−5.19, 2.03)		−1.27 (−4.94–2.40)
Triple	Ref	Ref		Ref
Double glazing at home		−1.00 (−2.49, 0.48)	−0.58 (−2.08–0.93)	−1.03 (−2.52–0.46)
Employed		0.84 (−1.28, 2.96)		0.94 (−1.18–3.06)
Crowded		0.42 (−1.06, 1.80)		0.47 (−1.00–1.94)

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*The models are additionally evaluated against a model with the noise term excluded.

†B=estimated change in systolic blood pressure (mmHg) per dB(A). 95% CI=95% confidence interval calculated by means of the standard error.

‡χ^2 test was statistically significant α<0.05.

Table 3 shows the fully adjusted associations (model 2) between aircraft and road traffic noise exposure at school and at home, and blood pressure and heart rate, for the pooled sample and the country specific samples.

Table 3 The association between noise exposure and blood pressure and heart rate changes, after adjustment for confounders (only children visiting their school for at least 1 year) (n=853)

Source of exposure	Place of exposure	Exposure metric	Outcome	Pooled sample (n=853) B (95% CI) (p)	UK sample (n =351) B (95% CI) (p)	NL sample (n= 502) B (95% CI) (p)
Aircraft noise	At school*	$L_{Aeq, 7–23hr}$	Systolic blood pressure	0.08 (−0.02–0.18) (0.10)	0.02 (−0.12–0.15) (0.77)	0.17 (0.01–0.33) (0.02)
			Diastolic blood pressure	0.05 (−0.04–0.14) (0.22)	0.01 (−0.09–0.12) (0.83)	0.20 (0.06–0.34) (0.00)
			Heart rate	0.05 (−0.06–0.15) (0.33)	0.01 (−0.13–0.16) (0.86)	0.08 (−0.11–0.27) (0.45)
	At home†	$L_{Aeq, 7–23hr}$	Systolic blood pressure	0.10 (0.00–0.20) (0.04)	0.03 (−0.10–0.17) (0.57)	0.17 (0.01–0.33) (0.03)
			Diastolic blood pressure	0.08 (−0.01–0.17) (0.05)	0.04 (−0.07–0.14) (0.43)	0.19 (0.05–0.32) (0.00)
			Heart rate	0.02 (−0.08–0.13) (0.61)	0.00 (−0.15–0.14) (0.95)	0.06 (−0.12–0.23) (0.51)
	At home†	$L_{Aeq, 23–7hr}$	Systolic blood pressure	0.09 (0.00–0.18) (0.03)	−0.01 (−0.13–0.12) (0.97)	0.19 (0.07–0.31) (0.00)
			Diastolic blood pressure	0.07 (−0.01–0.14) (0.08)	0.04 (−0.06–0.14) (0.35)	0.13 (0.01–0.24) (0.02)
			Heart rate	0.03 (−0.07–0.12) (0.50)	0.01 (−0.13–0.16) (0.84)	0.04 (−0.11–0.19) (0.55)
Road traffic noise	At school*	$L_{Aeq, 7–23hr}$	Systolic blood pressure	−0.11 (−0.21–0.00) (0.03)	−0.09 (−0.25–0.08) (0.22)	−0.14 (−0.27–−0.01) (0.02)
			Diastolic blood pressure	−0.04 (−0.13–0.06) (0.40)	0.02 (−0.11–0.15) (0.76)	−0.09 (−0.20–0.03) (0.09)
			Heart rate	−0.02 (−0.13–0.08) (0.62)	−0.11 (−0.28–0.07) (0.22)	0.02 (−0.14–0.17) (0.80)
	At home†	$L_{Aeq, 7–23hr}$	Systolic blood pressure		NA	−0.09 (−0.22–0.04) (0.16)

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*The model is adjusted for either aircraft or road traffic noise at school, centre (only for the pooled analysis), age, gender, ponderosity, school glazing, double glazing at home, employment status, crowding, home ownership, mother's education, ethnicity, cuff size, birth weight, parental high blood pressure, prematurity, and room temperature.

‡The model is adjusted for either aircraft or road traffic noise at home, centre (only for the pooled analysis), age, gender, ponderosity, double glazing at home, school glazing, employment status, crowding, home ownership, mother's education, ethnicity, cuff size, birth weight, parental high blood pressure, prematurity, and room temperature.

B=estimated change in blood pressure or heart rate per dB(A); 95% CI=95% confidence intervals calculated by means of the standard error; n=sample size, p=p value for association α<0.05, tested by means of a χ^2 test; NA= data not available.

After pooling the data, chronic aircraft noise at school ($L_{Aeq,\ 7–23hr}$) was related to a statistically non-significant increase in systolic (χ^2=2.7, df=1, p=0.10) and diastolic (χ^2=1.4, df=1, p=0.22) blood pressure and heart rate (χ^2=1.0, df=1, p=0.33). Chronic aircraft noise at home (expressed as $L_{Aeq,\ 7–23hr}$) was statistically related to systolic (χ^2=4.2, df=1, p=0.04) and diastolic (χ^2=3.9, df=1, p=0.05) blood pressure: increases of 0.10 (95% CI 0.00 to 0.20) and 0.19 (95% CI 0.05 to 0.32) mmHg/dB(A) were found for systolic and diastolic blood pressure, respectively. Chronic aircraft noise exposure during the night ($L_{Aeq,\ 23–7hr}$) at home was positively associated with blood pressure. Only for systolic blood pressure was this association statistically significant (χ^2=4.7, df=1, p=0.03): after pooling the data an increase of 0.09 (95% CI 0.00 to 0.18) mmHg/dB(A) was found.

The effect of chronic aircraft noise on blood pressure differed somewhat between the samples. In the Dutch sample, chronic aircraft noise exposure at school was related to an increase in blood pressure. Statistically significant increases of 0.17 (95% CI 0.01 to 0.33) mmHg/dB(A) and 0.20 (95% CI 0.06 to 0.34) mmHg/dB(A) were estimated for systolic and diastolic blood pressure, respectively. In the British sample, aircraft noise exposure at school was related to small and statistically non-significant increases in blood pressure. For diastolic blood pressure, the results differed statistically significantly between the samples (test of heterogeneity: χ^2=7.1, df=1, p=0.01). In relation to chronic aircraft noise at home (expressed as $L_{Aeq,\ 7–23hr}$ and $L_{Aeq,\ 23–7hr}$) similar differences between the samples could be observed (see also table 3).

Road traffic noise exposure

After pooling the data, chronic road traffic noise exposure at school ($L_{Aeq,\ 7–23hr}$) was related to a decrease in systolic and diastolic blood pressure. For systolic blood pressure this association was statistically significant: A decrease of −0.11 (95% CI −0.21 to 0.00) mmHg/dB(A) was estimated. A negative association was found between chronic road traffic noise exposure and heart rate: chronic road traffic noise exposure was related to a decrease in heart rate; this was not statistically significant. The effect of road traffic noise on blood pressure did not differ between the samples. The effects of road traffic noise exposure ($L_{Aeq,\ 7–23hr}$) at home were only investigated in the Dutch sample: road traffic noise at home was related to a statistically non-significant decrease in systolic and diastolic blood pressure.

Comparison with other studies

In figs 2 and 3, the results of the RANCH study are compared with other recent studies investigating the effects of noise on children's blood pressure. The figures show that small differences in blood pressure can be observed and that the effect of noise exposure on children's blood pressure differs among the studies.

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Figure 2 The association between noise exposure and systolic blood pressure in children. The dotted vertical line corresponds to no effect of noise exposure; with the exception of Morell-98,[19] the circles and horizontal lines correspond to the estimated change in blood pressure per 5 dB(A) increase in noise and 95% CI. For Morell-98,[19] the circles and horizontal lines correspond to the estimated change in blood pressure per 5 ANEI increase and 95% CI. With the exception of the results of the RANCH study and Morell-98,[19] the presented estimates of the other studies were not adjusted for confounders due to the fact that data were not available.

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Figure 3 The association between noise exposure and diastolic blood pressure in children. The dotted vertical line corresponds to no effect of noise exposure; with the exception of Morell-98,[19] the circles and horizontal lines corresponds to the estimated change in blood pressure per 5 dB(A) increase in noise and 95% CI. For Morell-98,[19] the circles and horizontal lines correspond to the estimated change in blood pressure per 5 ANEI increase and 95% CI. With the exception of the results of the RANCH study and Morell-98,[19] the presented estimates of the other studies were not adjusted for confounders due to the fact that data were not available.

Discussion

Aircraft noise

In this study, indications were found for a possible association between chronic aircraft noise and blood pressure. However, the effect of chronic aircraft noise on blood pressure differed between the samples: in the Dutch sample, aircraft noise exposure was related to increased blood pressure; this was not the case in the British sample. Due to the difference in exposure metrics and adjustment for confounders, comparison of the results of the RANCH study with other studies was difficult. Figures 2 and 3 show that for aircraft noise exposure, no consistent findings can be seen. The Los Angeles Airport Study showed that both systolic and diastolic blood pressure were higher in the children attending aircraft noise exposed schools than in children attending control schools.[13,14] Blood pressure differences of 2.9 mmHg for systolic blood pressure and 2.6 mmHg for diastolic blood pressure were found, while the difference in noise exposure levels ($L_{Aeq,\ 1hr\ indoor}$) between the exposed and the control group was 18 dB(A). Comparison of the blood pressure between two groups of children living around the old Munich Airport, exposed to high noise levels ($L_{Aeq,\ 24hr}$=68.1 dB(A)) or lower noise levels ($L_{Aeq,\ 24hr}$=59.2 dB(A)) showed that there was an increase of 1.92 mmHg for systolic blood pressure and a decrease of 0.17 mmHg for diastolic blood pressure.[16,17] Morell *et al* investigated the effects of aircraft noise exposure both at school and at home.[19] After adjustment for confounders, they found that both school and residential aircraft noise levels were negatively but statistically not significantly associated with systolic and diastolic blood pressure; for school exposure, regression coefficients of −0.017 and −0.043 for systolic and diastolic blood pressure respectively were found, corresponding with mean blood pressure differences of 0.5–1.3 mmHg across the whole noise range (15–45 ANEI).

Until now the effects of long term night-time noise exposure on the cardiovascular system have only been investigated in adults. In a recent German study the associations between night-time road traffic noise and several cardiovascular outcomes were found to be stronger than the associations for daytime noise.[20] Because the correlations between aircraft noise metrics were high in the RANCH study, it was not possible to disentangle the effects of school and home exposure (including the night period).

Road traffic noise

In the RANCH study, negative associations were found between chronic road traffic noise exposure and blood pressure. The results of previous studies investigating the effects of road traffic noise were not consistent (see also figs 2 and 3). Regecová and Kellerová found that children attending kindergartens situated in areas with traffic noise levels higher than 60 dB(A) had higher mean blood pressure than children in quiet areas.[15] Mean heart rate values tended to decrease with increasing traffic noise recorded at kindergartens, which was consistent with findings in the UK sample. In the Tyrol study, children exposed to higher levels of road and rail traffic noise (L_{dn} >60 dB(A)) had an elevated systolic blood pressure and only slightly elevated heart rate compared to children exposed to noise levels below L_{dn} 50 dB(A).[18] For diastolic blood pressure a decrease was found. Karsdorf and Klappach found a maximal difference of 16 mmHg for both systolic and diastolic blood pressure in girls, when comparing the blood pressure of children attending a quiet school with that of children attending a noisy school.[21]

A possible explanation for the unexpected road traffic noise effects might be the estimation of exposure to road traffic noise. Since children move to a different classroom each year during their time at school, road traffic noise exposure changes. Thus, the road traffic noise levels at the façade of their current classroom might not reflect the average level of exposure during their time at school.[10]

Differences between the samples

As already mentioned, the effect of aircraft noise on blood pressure differed between the samples. It is not possible to give an unequivocal explanation for these differences. Although noise levels in both samples were calculated according to a standardised protocol, differences in variations in flight patterns and differences in availability of the aircraft and road traffic fleet between the countries might have played a role. These could have lead to systematic biases and unexpected differences in the outcome.[22,23,24,25,26] There might be differences in frequency and type of insulation of both schools and homes, which could result in differences in the effect of noise on blood pressure, even though both design and analysis accounted for the influence of insulation.[10] Differences in schooling system and teachers' attitudes towards noise might have differential effects on the children's reactions to noise.

The British sample contained relatively more non-white children than the Dutch sample; the Dutch non-white group included Turkish and Moroccan children and children with a mixed background, while the British non-white sample included Pakistani and Indian children. Winkelby *et al* showed strong differences in blood pressure among different ethnic groups.[27] It appears that hypertension is very common in African cities and in black populations in Britain and the United States.[28] According to the Dutch Heart Foundation, the prevalence of high blood pressure among young foreigners (Turkish and Moroccans) varies from 2–10%; the variation among Dutch natives is 4–7%.[29] Due to these differences in ethnic composition of the samples, it is possible that statistical adjustment did not lead to a complete comparison. Because of differences in the ethnic composition between the samples, the impact of ethnicity on the association between noise exposure and blood pressure might differ between the British and Dutch samples. This might be a possible explanation for the differences found in the effect of aircraft noise on blood pressure between both samples. Furthermore, lifestyle factors such as salt intake and body exercise were not measured but might have played a role. None of the explanations mentioned in this section can be further investigated on the data available in the RANCH study.

Study strengths and limitations

This study had a relative large sample size; the participants were distributed over a broad exposure range by using a continuous noise exposure measure. To date, most studies investigating the impact of noise exposure have involved between-group comparisons (high versus low) or they have tended to create noise categories (e.g. high, medium, low) by using indicator terms for ordered polyotomous exposure categories. However, it is recognised that the results may be sensitive to decisions about cut-off points used to categorise continuous exposure variables and the method used to assign scores to exposure categories.[30] Furthermore, we were able to take into account a broad range of potential confounders and determinants which were gathered in a uniform way. Unlike previous studies, we took into account the hierarchical structure of the data. Finally, the current study investigated the effects of both school and home noise exposure, including night-time noise exposure. Despite the availability of these data, it was not possible to disentangle the effects of school and home exposure due to the high correlation between the aircraft noise metrics. Because the main objective of RANCH was to investigate the effects of noise exposure at school on children's cognition, noise exposure at home was not taken into account during the selection. Based on our study it is therefore not possible to draw definite conclusions about the relative importance of noise exposure at home and at school and possible interactions between home and school noise exposure.

The cross-sectional design of our study limits causal interpretations of the possible relation between noise exposure and blood pressure. The road traffic noise levels at the façade of the children's school might not reflect the average level exposure during their time at school. This might have biased the outcomes of our results.[10]

Interpretation of the findings

Due to the fact that the results of this study are not fully consistent and the inconsistency in the scientific literature, it is not possible to derive an exposure-effect relationship between noise exposure and children's blood pressure.

Additionally, it is unknown whether the effects of noise on blood pressure are reversible if exposure to noise ceases; in the Munich Airport study differences in reading score between the two exposure groups disappeared after removing the differences in noise exposure.[31] Finally, it is difficult to indicate whether and to what extent slight increases in children's blood pressure can cause possible health risks in later life. The degree of blood pressure elevations found in relation to noise exposure were small and the clinical significance of such minor changes in childhood blood pressure is difficult to determine. Findings could be due to chance. The extent of blood pressure elevations found are probably not significant for children during their youth, but could portend elevations later in life that might be health damaging.[32] In the literature it is suggested that increased blood pressure in children strongly predicts hypertension in young adults; essential hypertension and the precursors of cardiovascular disease might originate in childhood.[33,34,35,36,37]

Some studies, investigating the effects of noise exposure on children's blood pressure, interpret such findings as indicator of psychophysiological arousal.[16,17] However, another possibility is that the observed blood pressure elevations are vegetative responses. Since we found significant associations with night-time exposure, blood pressure elevations might also be seen as an effect of sleep disturbance.[20]

Main messages

- This epidemiological field study examined the effects of aircraft and road traffic noise exposure on primary school children's blood pressure around two European airports.
- On the basis of the RANCH results, considered in conjunction with results of previous studies, no univocal conclusions can be drawn about the relationship between community noise and children's blood pressure.

Policy implications

- For a better understanding of the underlying mechanisms, more research is indicated to disentangle the effects of different times of day, evening, and night.

Conclusion

The relationship between aircraft noise and blood pressure was not fully consistent: in the Dutch sample, blood pressure increased statistically significantly as aircraft noise exposure increased; this was not the case in the British sample. These findings, taken together with those from previous studies, suggest that no univocal conclusions about the association between aircraft noise exposure and blood pressure can be drawn.

The findings for road traffic noise were difficult to interpret, since negative associations were found between chronic road traffic noise exposure and blood pressure. Furthermore, the results of previous studies investigating the effects of road traffic noise were not consistent.

Based on our study it is not possible to draw definite conclusions about the relative importance of noise exposure at home and at school and possible interactions. For a better understanding of the underlying mechanisms, more research is necessary to disentangle the effects of home and school noise exposure.

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Abbreviations

ANEI - Australian Noise Exposure Index (this is a noise metric expressing the level of aircraft noise in Australia

as opposed to equivalent noise metrics (such as L_{Aeq} - $_{7–23hr}$) the ANEI not only takes into account the energy level of noise level events, but also the number of events and day/night loadings from social surveys in Australia)

dB(A) - unit of A-weighted sound pressure level, where A-weighted means that the sound pressure levels in various frequency bands across the audible range have been weighted in accordance with differences in hearing sensitivity at different frequencies

df - degrees of freedom

L_{Aeq} - A-weighted average sound pressure level

L_{Aeq} - $_{7–23hr}$, the average continuous equivalent sound level within a certain area from 0700 to 2300 hours within a specified period

RANCH - Road traffic and Aircraft Noise exposure and children's Cognition and Health: exposure-effect relationships and combined effects

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