ORIGINAL ARTICLE

Aircraft noise around a large international airport and its impact on general health and medication use

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Aims: To assess the prevalence of general health status, use of sleep medication, and use of medication for cardiovascular diseases, and to study their relation to aircraft noise exposure.
Methods: These health indicators were measured by a cross-sectional survey among 11 812 respondents living within a radius of 25 km around Schiphol airport (Amsterdam).
Results: Adjusted odds ratios ranged from 1.02 to 2.34 per 10 dB(A) increase in L_{den}. The associations were statistically significant for all indicators, except for use of prescribed sleep medication or sedatives and frequent use of this medication. None of the health indicators were associated with aircraft noise exposure during the night, but use of non-prescribed sleep medication or sedatives was associated with aircraft noise exposure during the late evening (OR = 1.72). Vitality related health complaints such as tiredness and headache were associated with aircraft noise, whereas most other physical complaints were not. Odds ratios for the vitality related complaints ranged from 1.16 to 1.47 per 10 dB(A) increase in L_{den}. A small fraction of the prevalence of poor self rated health (0.13), medication for cardiovascular diseases or increased blood pressure (0.08), and sleep medication or sedatives (0.22) could be attributed to aircraft noise. Although the attributable fraction was highest in the governmentally noise regulated area, aircraft noise had more impact in the non-regulated area, due to the larger population.
Conclusions: Results suggest associations between community exposure to aircraft noise and the health indicators poor general health status, use of sleep medication, and use of medication for cardiovascular diseases.

The continuing growth of air transportation may put pressure on the environment, especially in densely populated areas. People living near airports are concerned about health effects of aircraft related pollution and safety. These concerns are substantiated by findings that aircraft noise may have adverse health effects such as annoyance, sleep disturbance, and cardiovascular diseases.[1–7]

Since the 1960s many community surveys around airports have been conducted. Fields[8] identified 521 social surveys, published in English between 1943 and 2000, on residents' reactions to environmental noise in residential areas. Most of these studies measured annoyance. Some also measured general health and medication use and reported associations between self-rated health status or self-reported health complaints and aircraft noise exposure.[2 9–13] Several studies found an association between use of medication for sleep or cardiovascular diseases and aircraft noise levels,[14–16] but others reported no associations.[17] Knipschild,[14 18] one of the first to study self-reported health problems and use of cardiovascular drugs in a series of community surveys around Schiphol airport, found an increased use of cardiovascular drugs in areas with high aircraft noise levels. He also found a relation between aircraft noise exposure and the contact rate with general practitioners, especially for psychological problems, psychosomatic symptoms, and cardiovascular diseases. A more recent study on the use of medication around Schiphol airport, based on automated pharmacy registrations, suggested a relation between aircraft noise exposure and the use of sedatives.[19]

At the beginning of the 1990s, plans were made to expand Schiphol airport with a fifth runway. Schiphol is situated in a densely populated area on the outskirts of Amsterdam. It is the fourth international airport in Europe with 432 thousand aircraft movements, 39.5 million passengers, and 1183 thousand tons of freight.[20] Due to the expansion from four to five runways, the Dutch government initiated the Health Impact Assessment Schiphol Airport (HIAS), a long term research programme on health effects of environmental pollution around Schiphol airport.

The first phase of HIAS was part of an Environmental Impact Assessment (EIA) showing that exposure to aircraft noise caused annoyance, sleep disturbance, cardiovascular disease risk, and reduced performance.[21] The authors concluded that local air pollution levels were probably not associated with health effects such as respiratory diseases or cancer. Further research was recommended for several health indicators, for example, medication use, birth weight, cardiovascular diseases, annoyance, sleep disturbance, and neurobehavioural effects. This was realised in the second phase of the HIAS. Health impact assessments such as this one are currently considered necessary,[4] and are required under the EU programme of community action in the field of public health.[22]

Here we present results from a questionnaire survey, which was part of HIAS phase II.[23 24] Its two objectives were: (1) to assess the prevalence of annoyance, sleep disturbance, self-rated general health status, respiratory complaints, medication use, perceived risk, and residential satisfaction in the Schiphol region; and (2) to study the relation of these variables with aircraft noise exposure and/or air pollution. The selection of these health indicators was based on recommendations formulated in phase I of the HIAS and by local environmental action committees. The focus of this article is on general health status, use of sleep medication, and use of medication for cardiovascular diseases in relation to aircraft noise exposure.

Main messages

- Exposure to aircraft noise at levels above 50 dB(A) L_{den} may contribute to a poorer general health status.
- Exposure to aircraft noise may be a risk factor for cardiovascular diseases.
- Exposure to aircraft noise during the late evening is associated with the intake of non-prescribed sleep medication or sedatives.
- The number of people suffering health effects due to aircraft noise is dominated by the large number of people that is exposed to relatively moderate to low noise levels, not by those exposed to high noise levels.

Policy implications

- Effects of aircraft noise are not limited to annoyance reactions, but also include other health effects such as poorer general health, cardiovascular diseases, and sleep disturbance.
- Policy measures to reduce community exposure to aircraft noise should not only be concentrated on areas exposed to high aircraft noise levels.
- If expansion of the airport capacity will increase the number of moderate and low exposed people, the overall impact on public health is likely to also increase.

MATERIALS AND METHODS

Study design

We conducted a postal questionnaire among adults (18 years and older) between November 1996 and February 1997 in an area with a radius of 25 kilometres around the airport (fig 1), inhabited by almost 2 million people; approximately 1.5 million of these were aged 18 years and older. The questionnaire comprised questions on annoyance, sleep disturbance, general health status, respiratory complaints, medication use, perceived risk, and residential satisfaction. It also solicited information on potential determinants of these variables, such as personal characteristics, living situation, and smoking behaviour. Questions were derived, where possible, from existing, validated questionnaires.

We used stratified random sampling of 31 000 addresses, which were obtained from the Netherlands Post and Telecommunications company. The desired sample size was calculated according to Kirkwood[25] for two expected effects: annoyance due to noise and respiratory complaints. Background prevalences for annoyance and respiratory complaints were 10% and 3.6% respectively. Aircraft noise was assumed to increase the prevalence of annoyance by 25–50% and air pollution was assumed to increase the prevalence of respiratory complaints by 50–100%. Power calculations were performed for an area with high noise levels (>35 Kosten units; for a description of Kosten units refer to the ''exposure assessment'' section) and one with low levels (<35 Ke) with equal group sizes in each area. The power was 80% and the confidence limit 5%. Based on these calculations a random sample of 5000 people would be sufficient. However, fewer people live in high noise areas than in low noise areas; it is desirable that the former should be over-represented in the sample. The second form of stratification is based on the accuracy required to be able to observe differences in prevalence over time, in areas that at present have low noise levels. Over-representation of these areas is also desirable. On the basis of these considerations it was decided that a net sample size of 10 000 people would be required. Given an expected response rate of 25–35%, a random sample of 30 000 addresses from a radius of 25 km around the airport would be needed to achieve this net result.

The sample was stratified by aircraft noise exposure (10 categories) and distance to the centre of the airport (five categories). The stratification was carried out in a geographic information system (Arc/Info 7.2.1), by combining a digital map containing aircraft noise contours with a map containing distance contours. This combined map was again superimposed on a digital map containing address coordinates. The thinly populated areas, closer to the airport and with higher noise levels, contained too few addresses to adequately fill the sample cells. In these cells, all existing addresses were included in the sample, and the smaller number of addresses was compensated for in other cells with the same noise levels where possible. Questionnaires were sent to 30 216 addresses. Non-respondents received a reminder letter after a few weeks.

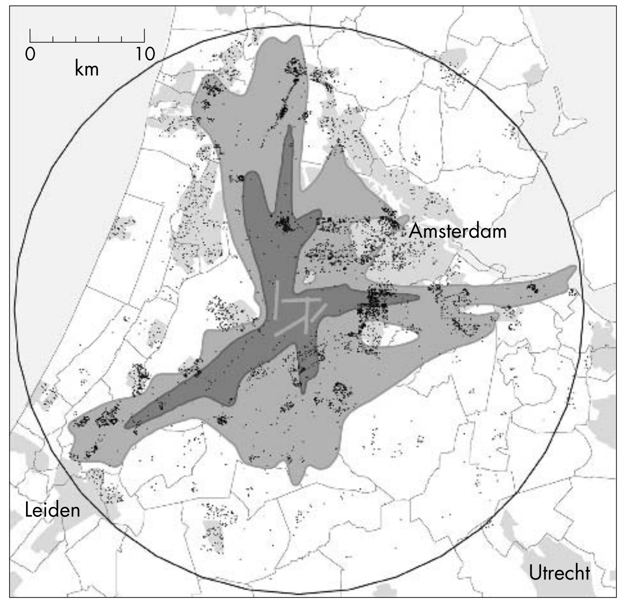

Figure 1 Study area with 20 and 35 Kosten unit contours (1996). The circle represents a distance of 25 kilometres around Schiphol. The dots show the residential locations of the respondents.

Health indicators

The general health status was measured in two ways, both widely used in (Dutch) health care research:

- With a single question: ''How is your health in general?''. Most health surveys ask similar kinds of questions, but there is still no standard formulation for this question. We used one that has been applied in Dutch national health surveys since 1983, and can be answered on a five point scale: (1) very good, (2) good, (3) moderate, (4) sometimes good and sometimes bad, (5) bad. For analysis the variable was dichotomised into ''good'' (categories (1) and (2)) and ''poor'' (the last three categories).[26]
- With a 13 item questionnaire (VOEG), consisting of a list of health complaints. The VOEG questionnaire was originally designed in the Netherlands to measure stress in industrial situations,[27] but is currently also commonly applied in general health surveys.[28] It covers items such as

physical complaints (for example, back pain), and symptoms reflecting vitality (for example, tiredness, listlessness). Respondents indicate which symptoms were present ''lately''. The total number of symptoms reported by a respondent is the VOEG score (with a minimum of 0 and a maximum of 13); a higher VOEG score indicates a poorer self-rated health. For analysis the VOEG was dichotomised: respondents with six or more symptoms were defined as having a ''poor self-rated health''. In addition, each of the 13 items was analysed separately.

We assessed use of medication for cardiovascular diseases or increased blood pressure and use of sleep medication or sedatives, whether on doctor's prescription or as self-medication. Respondents could indicate which medication was used in the 12 months prior to the moment of questioning. For medication for cardiovascular diseases and increased blood pressure, we only analysed prescribed medication, as this is rarely used without prescription (1% in this study). For sleep medication or sedatives we analysed both prescribed and non-prescribed medication. Respondents could also report the frequency of use of sleep medication or sedatives. This was measured on a four point scale: (1) every night, (2) regularly, (3) occasionally, (4) never. For analysis this variable was dichotomised: respondents who used sleep medication or sedatives ''every night'' or ''regularly'' were defined as frequent users, respondents who used these medicines ''occasionally'' or ''never'' were defined as non-frequent users.

Exposure assessment

The National Aerospace Laboratory, using a mathematical model of the annual exposure to aircraft noise around Schiphol airport calculated aircraft noise levels. Several annual average aircraft noise measures for 1996 were calculated at the geographical location of each respondent's residence. Since we did not have the x and y coordinates of the actual residential addresses, we took the closest alternative, being the x and y coordinates of the geometric centre of the six digit postal code area of each residential address. These areas cover on average 17 addresses. For the analyses we used the following noise measures: L_{den}, $L_{Aeq,\ 23–07\ h}$, and $L_{Aeq,\ 22–23\ h}$, expressed in dB(A) (A-weighted decibels), and the Kosten unit. L_{den} (day, evening, night) is an equivalent sound level over 24 hours in which sound levels during the evening (19 00–23 00 hours) are increased by 5 dB(A) and those during the night (23 00–07 00 hours) by 10 dB(A). As a result of these penalties for the evening and night, the L_{den} value is equal to, or larger than, the $L_{Aeq24\ h}$ value, the difference depending on the distribution of the traffic over the day, evening, and night period. $L_{Aeq,\ 23–07\ h}$ and $L_{Aeq,\ 22–23\ h}$ are also equivalent sound levels, calculated over the corresponding time periods. The Kosten unit is a commonly used measure for aircraft noise in the Netherlands, developed by the Kosten Committee in 1963.[29] With the fifth runway that became operational at Schiphol airport in January 2003, the Kosten unit is officially replaced by the noise measure L_{den}. The L_{den} value is approximately equal to (0.5 * Kosten unit + 41).[30]

Non-response follow up

To examine selective non-response, a follow up telephone interview was carried out among 500 non-respondents. The sample of non-respondents was randomly selected from all addresses in the initial sample from which no response was received as of 31 January 1997 (n = 17 840).

These non-respondents were asked for their sociodemographic characteristics (gender, age, education, and country of origin), the reason for not responding, their annoyance due to aircraft noise, their concern about safety because of living close to a large airport, and their attitude regarding the expansion of Schiphol airport. The questions were identical to the corresponding questions in the original, postal questionnaire. Results from this survey indicated that selective non-response was likely. Non-respondents suffered less annoyance due to aircraft noise, were less concerned about airport safety, and had a less negative attitude regarding the expansion of Schiphol. The non-respondent group was less highly educated and comprised more people of foreign origin.

Statistical analysis

All statistical analyses were performed with SAS 8.02. Observations were suitably re-weighted to take the stratified study design into account, and weighted overall prevalences of the health indicators were calculated. The association between the health indicators and aircraft noise exposure was assessed using a multiple logistic regression model, controlling for potential determinants such as age, sex, education level, country of origin, smoking behaviour, and degree of urbanisation. In the analyses of self-rated health, we also controlled for the number of household members and home ownership. To assess linearity of the relation, the aircraft noise measure was included continuous as well as categorised (in categories of 5 dB(A)). Both prevalences and odds ratios (ORs) were calculated with and without the non-response weighting factor (see section on non-response bias), to judge the sensitivity of results to selection bias. In the regression analyses for sleep medication or sedatives (prescribed and non-prescribed) and frequent use of sleep medication or sedatives, we excluded respondents who also took medication for cardiovascular diseases or increased blood pressure, and/or who took medication for rheumatism or painful joints, and/or who regularly worked night shifts. These variables might bias the relation between exposure and response.

Population attributive risks

To estimate how much of the prevalence of a health effect was attributable to aircraft noise, population attributive risks (PARs) were estimated for the area with aircraft noise levels of 20 Kosten units or more (approximately $\geqslant$50 dB(A) L_{den}), and 35 Kosten units or more (approximately $\geqslant$58 dB(A) L_{den}). The attributable fraction was defined as the prevalence of health effects caused by aircraft noise divided by the overall prevalence. PARs were estimated for poor self-rated health (single question), medication for cardiovascular diseases or increased blood pressure, and prescribed sleep medication or sedatives. Since there was no evidence for threshold levels of noise for health effects, a sensitivity analysis on the noise exposure measure was carried out. The following variants were calculated: (1) the noise level was included in the regression model as a continuous variable, with the reference value of the noise level set to zero, that is, with the assumption that there is no threshold; (2) the noise level was included in the regression model as a continuous variable, with the reference value of the noise level set to 10 Kosten units (approximately 46 dB(A) L_{den}), that is, it is assumed that no health effects result from aircraft noise below a threshold of 10 Kosten units; (3) the noise level was categorised into intervals, with 10 Kosten units or less as reference interval.

Non-response bias

We conducted a sensitivity analysis to estimate the impact of non-response. Data from a combined data set of respondents (n = 11 812) and non-respondents (n = 271) were used to estimate selection bias. We evaluated various prevalence estimates using logistic regression analysis, with ''group'' as

Table 1 Number of respondents and chance (p values, below) to end up in the sample per sample stratum; the number of non-respondents per exposure stratum are in parentheses

Kosten units	Distance in km ⩽5	>5–10	>10–15	>15–20	>20–25	Total response	(non-respondents)
<20	33	595	766	750	543	2687	(45)
	0.05	0.01	0.01	0.01	0.01	0.01	
⩾20–25	128	601	457	320	395	1901	(59)
	0.06	0.02	0.02	0.03	0.02	0.02	
⩾25–30	104	736	513	602	421	2376	(51)
	0.05	0.03	0.07	0.13	0.17	0.06	
⩾30–35	224	655	520	182	×	1581	(26)
	0.37	0.10	0.16	0.33		0.14	
⩾35–40	138	802	341	55	×	1336	(44)
	0.46	0.26	0.43	0.40		0.30	
⩾40–45	80	890	126	×	×	1096	(26)
	0.41	0.37	0.56			0.39	
⩾45–50	47	528	6	×	×	581	(17)
	0.55	0.35	0.36			0.36	
⩾50–55	47	179	4	×	×	230	(3)
	0.43	0.41	0.64			0.42	
⩾55–60	9	11	×	×	×	20	(0)
	0.33	0.75				0.46	
⩾60	4	×	×	×	×	4	(0)
	0.45					0.45	
Total response	814	4997	2733	1909	1359	11812	
(non-response)	(52)	(95)	(46)	(47)	(31)		(271)

×, noise-distance combination does not occur.

the dependent variable (1 = respondent, 0 = non-respondent). Five models were estimated, each with a different explanatory variable: noise level, distance to the centre of the airport, annoyance due to aircraft noise, concern about airport safety, and attitude regarding the expansion of Schiphol. Each of the five models was further adjusted for age, gender, education, and country of origin. This resulted in five different weighting factors for each respondent, based on his or her score on the variables in these five models. The weighting factor was 1 divided by the probability (p) of response (W_1), divided by the average of W_1. The non-response weighting factors varied from 0.01 to 17.6. This method indicated substantial influence of non-response in the analysis of noise annoyance,[23 24] but only minor influence on the effects published here.

RESULTS

The final response rate was 39% (n = 11 812). The response rate of the non-response survey was 54% (n = 271). Table 1 shows the distribution of respondents and non-respondents among the exposure strata. Table 2 describes the aircraft noise exposure measures that were used in the analyses. The different noise measures are highly correlated (Pearson's $r > 0.90$). Table 3 shows the characteristics of the study population. Respondents are evenly distributed between the two sexes. Over 40% of the respondents are aged 35–54 years, and nearly half have an intermediate education level. There are few respondents of non-Dutch origin. These variables are more or less evenly distributed among the different noise level categories, except for degree of urbanisation (air traffic is preferably routed across rural area). Table 4 shows prevalences of the health indicators. The overall prevalence of poor self-rated health is comparable to the prevalence in the general Dutch population in 1996 (19%).[31] The average VOEG score is 3.1 (SD 2.8), compared to 2.6 in the general Dutch population.[32] Pain in bones and muscles, feelings of tiredness, and back pain are the most prevalent health complaints (38–41%). Pain in the chest or cardiac region, upset stomach, and dizziness are least prevalent (13–14%). The prevalences of medication use could not be compared to Dutch reference figures, due to differences in the phrasing of questions.

The effect of the non-response weighting factors on the prevalence estimates was assessed, and the differences in estimated prevalences were negligible. In table 4 we show the effect of the weighting factor based on the model with "annoyance due to aircraft noise" as the explanatory variable. It shows that non-response had only minor influence on the results; the overall prevalence varied only 0–2%. Results for the other four models were similar.

Exposure-response relations

Figures presented here are not weighted for non-response, as use of the non-response weighting factor in our regression models did not affect the results. Table 5 presents the associations between health indicators and aircraft noise exposure measures. Associations with L_{den} are all positive and statistically significant, except for prescribed sleep medication or sedatives and its frequent use. The health indicators do not appear to be related to noise exposure during the night ($L_{Aeq,\ 23–07\ h}$). However, the use of non-prescribed sleep medication or sedatives is associated with aircraft noise exposure in the late evening ($L_{Aeq,\ 22–23\ h}$) with an OR of 1.72. Analyses of the separate VOEG items showed statistically significant relations of L_{den} with six health complaints (ORs for an increase of 10 dB(A)): shortness of breath (OR = 1.29, 95% CI 1.09 to 1.53); feelings of tiredness (OR = 1.34, 95% CI 1.17 to 1.53); headache (OR = 1.16, 95% CI 1.01 to 1.34); tired sooner than considered normal (OR = 1.47, 95% CI 1.26 to 1.70); listlessness (OR = 1.17, 95% CI 1.01 to 1.36); and tired and not fully rested in the morning (OR = 1.20, 95% CI 1.03 to 1.41). For the remaining seven complaints the ORs were lower, ranging from 0.99 to

Table 2 Description of the aircraft noise exposure measures in the study population

Exposure measure	Range	Average	SD
L_{den}	41–76 dB(A)	51.3	3.1
$L_{Aeq,\ 22–23\ h}$	36–70 dB(A)	44.3	4.1
$L_{Aeq,\ 23–07\ h}$	32–65 dB(A)	37.9	4.0
Kosten units	0–64 Kosten units	17.3	6.8

Table 3 Characteristics of the study population per category of L_{den}, in percentages

L_{den} in dB(A)	<50	50–55	55–60	≥60	Total*	Total†
Sex (n = 11601)						
Male	50	53	54	53	52	49
Female	50	47	46	47	48	51
Age (n = 11481)						
18–34	30	28	21	24	28	34
35–54	39	40	38	40	40	38
55–74	24	26	33	28	26	21
≥75	7	6	8	8	6	8
Education level (n = 11220)						
None and lower	17	19	21	21	18	
Intermediate	46	46	50	48	47	
Higher	37	35	29	31	35	
Country of origin (n = 11335)						
Netherlands	95	94	94	96	95	
Other	5	6	6	4	5	
Smoking behaviour (n = 11509)						
Never smoked	37	37	39	40	37	
Ex-smoker	34	34	35	33	34	
Smoker	29	29	26	27	29	
Degree of urbanisation (n = 11812)						
Rural/slightly urban	26	15	35	54	20	
Urban/strongly urban	39	54	35	18	48	
Extremely urban	35	31	30	28	32	

*Total in the study population.
†Total in the overall population of study area. Source: Statistics Netherlands, 1 January 1998.

1.17, and not statistically significant. Table 6 shows the relation of the health indicators with L_{den} when this noise measure was categorised. The ORs tend to rise with increasing noise levels, but differences between the categories are not statistically significant. When the regression analyses for sleep medication or sedatives (prescribed, non-prescribed, and frequent use) were repeated without excluding the possibly modifying variables described under ''materials and methods'', similar results were obtained. In addition to health determinants, degree of urbanisation was also considered a potential determinant. However, omitting this determinant from our analyses did not substantially alter the results.

Population attributive risks

Table 7 shows results of the PAR analyses. The PARs vary for the three models tested. The PARs are naturally highest when the noise measure is included in the model as a continuous variable with reference value set to zero, and the model with a categorised noise measure gives the lowest PARs. Due to the low precision of the relation between exposure and response in areas with low aircraft noise exposure, the figures for the 20 Kosten unit zone show a wide range in the estimates. The confidence interval on either side of the point estimate is so wide that negative values are possible. In this zone the maximum attributable fraction for aircraft noise was 0.13 for poor self-rated health, 0.08 for medication for cardiovascular diseases or increased blood pressure, and 0.22 for sleep medication or sedatives.

DISCUSSION

Our main aims were to assess the prevalence of health indicators in the Schiphol region, in relation to aircraft noise

Table 4 Prevalences of the health indicators in the study population

	n_{effect}	% overall prevalence	% after non-response weighting
Poor self-rated health (based on single question)	2301	20	20
Poor self-rated health (based on VOEG* score)	2157	20	19
Items of VOEG* questionnaire:			
Bloated or heavy feeling in the gastric region	2149	19	18
Shortness of breath	2105	19	19
Pain in the chest or cardiac region	1412	13	13
Pain in bones and muscles	4240	38	38
Feelings of tiredness	4431	40	38
Headache	3786	34	33
Back pain	4643	41	41
Upset stomach	1582	14	14
Benumbed feeling or tingling in limbs	2584	23	24
Tired sooner than considered normal	2805	25	24
Dizziness	1524	14	14
Listlessness	2866	26	25
Tired and not fully rested in the morning	2595	23	22
Use of medication for cardiovascular diseases or increased blood pressure	1750	15	17
Use of prescribed sleep medication or sedatives	1231	10	11
Use of non-prescribed sleep medication or sedatives	647	5	5
Frequent use of sleep medication or sedatives	528	5	5

*For a description of VOEG, refer to the ''materials and methods'' section.

Table 5 Odds ratios (OR) and 95% confidence intervals (CI) after multiple logistic regression of health indicators, in relation to various noise exposure measures per 10 dB(A) increase in noise levels, controlling for potential determinants

Health indicator	n_{total}	n_{effect}	Noise measure	OR	95% CI
Poor self-rated health (single question)	10412	1969	L_{den}	1.23	1.04 to 1.46
			$L_{Aeq,\ 23–07\ hrs}$	1.05	0.91 to 1.22
Poor self-rated health (VOEG score)	9887	1871	L_{den}	1.21	1.02 to 1.43
			$L_{Aeq,\ 23–07\ hrs}$	1.08	0.94 to 1.25
Medication for cardiovascular diseases/increased blood pressure	10105	1316	L_{den}	1.30	1.06 to 1.60
			$L_{Aeq,\ 23–07\ hrs}$	1.13	0.94 to 1.35
Prescribed sleep medication or sedatives	7240	516	L_{den}	1.25	0.93 to 1.68
			$L_{Aeq,\ 23–07\ hrs}$	0.91	0.70 to 1.18
			$L_{Aeq,\ 22–23\ hrs}$	1.26	0.99 to 1.60
Non-prescribed sleep medication or sedatives	7240	309	L_{den}	2.34	1.63 to 3.35
			$L_{Aeq,\ 23–07\ hrs}$	1.20	0.87 to 1.65
			$L_{Aeq,\ 22–23\ hrs}$	1.72	1.27 to 2.32
Frequent use of sleep medication or sedatives	7175	189	L_{den}	1.02	0.63 to 1.65
			$L_{Aeq,\ 23–07\ hrs}$	1.36	0.91 to 2.04
			$L_{Aeq,\ 22–23\ hrs}$	1.15	0.78 to 1.70

exposure, as a baseline for monitoring future changes in health status due to the expansion of Schiphol airport and changing exposure patterns. The prevalences of the health indicators in the research area were similar to available reference figures for the Dutch population. Despite ''normal'' prevalences, the risks of both poor self-rated health and of medication use for sleep and cardiovascular diseases increased with aircraft noise levels.

The location of a large international airport may influence the social structure of the population, for example by lowering house prices, and selecting lower social classes with poorer health status. If so, the effects of aircraft noise would be overestimated. In studying the associations between the health indicators and aircraft noise exposure we controlled for a number of potential health determinants, such as lifestyle, personal characteristics, and social economical status. However, there may also be selection effects in the other direction, for example when sensitive subjects have moved out of the high noise areas, which leads to underestimating the effects of noise.[33] Since it is difficult to study selection in a cross-sectional design, the impact of selection on the results of this study cannot be estimated. Therefore, conclusions on the causality of associations have to be tentative. However, there are no indications that these phenomena play a role around Schiphol airport. Another, related, drawback of a cross-sectional study is that one cannot determine whether (accumulation of) exposure preceded the reported health complaints.[34 35] To minimise this problem retrospective exposure data should be collected. The main aim of this study, however, was to assess baseline prevalence data for monitoring future (changes in) health status. From this perspective detailed estimation of retrospective exposure was not needed.

Proper assessment of subjects' exposure levels is of great importance. Besides aircraft noise, people are exposed to other noises, for example, noise at work, which could be the main reason for health effects or at least interact with residential noise. Also, exposure history plays a role in the development of health effects. We obtained information on retrospective exposure and exposure at work by asking people

Table 6 Odds ratios (OR) and 95% confidence intervals (CI) after multiple logistic regression of health indicators per category of L_{den}, controlling for age, sex, education level, country of origin, smoking behaviour, and degree of urbanisation

Health indicator	L_{den} in dB(A)	n_{total}	n_{effect}	OR	95% CI
Poor self-rated health (single question)	<50	3012	519	1.00*	
	50–55	6505	1266	1.09	0.97 to 1.23
	55–60	786	160	1.01	0.82 to 1.25
	⩾60	109	24	1.30	0.79 to 2.12
Poor self-rated health (VOEG score)	<50	2836	508	1.00*	
	50–55	6208	1183	1.07	0.95 to 1.21
	55–60	741	154	1.13	0.92 to 1.40
	⩾60	102	26	1.61	1.01 to 2.56
Medication for cardiovascular diseases/ increased blood pressure	<50	2935	334	1.00*	
	50–55	6279	830	1.18	1.01 to 1.38
	55–60	780	134	1.26	0.98 to 1.61
	⩾60	111	18	1.22	0.67 to 2.21
Prescribed sleep medication or sedatives	<50	2173	141	1.00*	
	50–55	4449	326	1.15	0.93 to 1.42
	55–60	541	42	1.13	0.78 to 1.64
	⩾60	77	7	1.52	0.67 to 3.42
Non-prescribed sleep medication or sedatives	<50	2173	70	1.00*	
	50–55	4449	203	1.59	1.20 to 2.11
	55–60	541	31	1.89	1.21 to 2.95
	⩾60	77	5	2.02	0.77 to 5.30
Frequent use of sleep medication or sedatives	<50	2159	58	1.00*	
	50–55	4402	110	0.91	0.65 to 1.27
	55–60	539	18	1.12	0.64 to 1.95
	⩾60	75	3	1.66	0.50 to 5.50

*Reference category.

Table 7 Percentage of poor self-rated health and medication use which is attributable to aircraft noise, in areas exposed to 20 Kosten units or more*, and 35 Kosten units or more†

Variable	Percentage of people reporting health effect	Attribution to aircraft noise (%), range of 3 models	Attributable number in population age ⩾18 years
Poor self-rated health			
⩾20 Kosten units*	21	−0.4 to 2.8	−1500 to 10400
⩾35 Kosten units†	21	2.3 to 4.4	500 to 1000
Use of medication for cardiovascular diseases or increased blood pressure			
⩾20 Kosten units	17	0.6 to 1.4	2200 to 5200
⩾35 Kosten units	18	1.7 to 2.3	400 to 500
Use of prescribed sleep medication or sedatives			
⩾20 Kosten units	10	1.2 to 2.2	4400 to 8100
⩾35 Kosten units	11	2.6 to 3.6	600 to 800

*An area with approximately 370 300 inhabitants (age 18 years and older).
†An area with approximately 23 500 inhabitants (age 18 years and older).

how long they had lived in their present house and neighbourhood and to what extent they were exposed to aircraft noise at work. The average residential time in the house and neighbourhood was 14 (±12) and 17 (±15) years, respectively; 51% of the respondents had lived longer than 10 years in their neighbourhood. About 6% of the respondents indicated that they were highly exposed to aircraft noise at work. However, these questions are only a proxy for past exposure, and some misclassification cannot be ruled out. This might under- or over-estimate the effects of aircraft noise on health, depending on whether previous exposure was higher or lower than the exposure assessed at the time of study.

The geo-referencing of individuals to specific locations, instead of larger regions, decreases the chance of non-differential misclassification with respect to exposure.[36] In this survey, we geo-referenced subjects using the geometric centre of six digit postal code areas (PCAs) of subjects' residential addresses. These PCAs merely cover parts of streets in high density areas. To investigate its accuracy in less populated areas, we examined those addresses in the study population that were situated in the least densely populated areas. Of all respondents, 12% lived in six digit PCAs with a geometric centre that was more than 100 metres away from the nearest six digit PCA. Only 3% lived in six digit PCAs of which this distance was more than 200 metres. Since these addresses were evenly spread across the whole research area, misclassification in this group was assumed minor and unlikely to have a considerable impact on the results.

To attain the objectives of our study, we targeted approximately 10 000 completed questionnaires, but as the final response rate (39%) was higher than the expected rate of 25–35% our actual sample was larger. Nevertheless, the non-response group was still large enough to potentially cause under- or over-estimation of prevalences. In the analysis of noise annoyance, sensitivity analysis showed substantial influence of non-response on the prevalence. Although sensitivity analysis showed that weighting for non-response had little effect on estimates presented here, we cannot entirely exclude non-response bias. For example, we may have omitted variables in the non-response survey that explain differences between respondents and non-respondents. If non-response bias was still present, it may have affected the prevalences and PARs, but is unlikely to have substantially affected the exposure-response relations.

We carried out stratified random sampling. Observations were re-weighted to take the stratified study design into account. However, when comparing the distribution of age and sex in the respondents with the distribution of age and sex in the study area, the younger age group (18–34 years) is under-represented, while the older age group (55–74 years) is slightly over-represented. This is a common feature in these types of surveys. The distribution of sex is comparable in both groups, but there might be some bias due to difference in age distribution. This may have slightly overestimated the prevalences. However, an effect on the exposure-response relations and PARs is not expected, since these were adjusted for age.

Regression analyses of the two general health indicators gave consistent results. Both the single question and the VOEG were associated with annual average aircraft noise levels (L_{den}). Analysis of the separate health complaints of the VOEG showed that mainly vitality related health complaints, such as tiredness and headache, were associated with aircraft noise exposure. The use of non-prescribed sleep medication or sedatives was associated with aircraft noise exposure during the late evening ($L_{Aeq,\ 22–23\ h}$), but not with the exposure during the night ($L_{Aeq,\ 23–07\ h}$). This suggests that exposure to aircraft noise at times that people go to bed stimulates the use of sleep medication or sedatives. The use of prescribed sleep medication or sedatives was positively related to L_{den} and $L_{Aeq,\ 22–23\ h}$ (OR 1.25 and 1.26, respectively), but these ORs were not statistically significant. Van Willigenburg and colleagues,[19] who studied the use of prescribed sleep medication by pharmacy registration data found that the use of prescribed sleep medication was associated with aircraft noise exposure. The increased tendency to use non-prescribed sleep medication might be due to the fact that people rarely visit their general practitioner for noise related sleep problems. They might consider their sleep problems of minor importance and therefore prescription of stronger sedatives by a general practitioner unnecessary. The prevalence of prescribed drugs might be determined by other determinants, for example, the prescription behaviour of general practitioners. They might tend to not easily prescribe sleep medication for sleep complaints due to aircraft noise, which may mask the effects of aircraft noise.

PAR analyses provided estimates of the number of people in the study area suffering health effects due to aircraft noise exposure, and thereby the potential health gain of removing noise exposure. These analyses assume that the statistical association between the noise level and the effect reflects a causal relation and is not due to confounding, for example. The estimates proved sensitive to assumptions about threshold levels and the scale of measurement of noise levels (continuous versus intervals). From these PAR calculations, we estimated that between a few hundred and about one thousand people, living in the area with noise levels of 35 Kosten units or more, reported health effects. Until recently, the 35 Kosten unit zone was the area for which most governmental policies were formulated and regulations applied. PAR estimates for the area with noise levels of 20–35 Kosten units indicate that thousands of people are affected. If exposure-response relations are also applied in areas with noise levels <20 Kosten units, the number of people with health effects due to aircraft noise in the total research area would be two to three times higher than that in the area ⩾20 Kosten units. It is worth noting that the number of people suffering these effects is dominated by the large number of people who are exposed to relatively moderate to low noise levels, not by those exposed to high noise levels.

Our findings are broadly consistent with what has been reported in the literature.[2 7 9–14 18] However, direct comparison of our results with those from other noise effects surveys is hampered by, for example, differences in phrasing and scoring of questions, different outcome measures or risk estimates, and different exposure measures. To improve comparability of various noise effects surveys in the future, the International Commission on the Biological Effects of Noise (ICBEN, Team No. 6: community response) has set the long term goal of developing questionnaire guidelines for noise effects research in social surveys. As a start, the German Ruhr University has developed a database of questionnaires on noise effects[37] to provide researchers a means to compare the operationalisation of health outcomes and confounding or moderating variables. Without further standardisation of research, inter-study and international comparisons will remain difficult.

In conclusion, we found associations between health indicators (general health status, use of medication for cardiovascular diseases or increased blood pressure, and use of sleep medication or sedatives) and the aircraft noise exposure measure L_{den}. None of the health indicators were associated with aircraft noise exposure during the night ($L_{Aeq,\ 23–07\ h}$), but use of non-prescribed sleep medication or sedatives was associated with aircraft noise exposure during the late evening ($L_{Aeq,\ 22–23\ h}$). Further, vitality related health complaints such as tiredness and headache were associated with aircraft noise, whereas most other physical complaints were not. In the area with aircraft noise exposure levels ⩾20 Kosten units, a small fraction of the prevalence of poor self-rated health (0.13), medication for cardiovascular diseases or increased blood pressure (0.08), and sleep medication or sedatives (0.22) could be attributed to aircraft noise. Although the attributable fraction was highest in the governmentally noise regulated area, aircraft noise had more impact in the non-regulated area, due to the larger population exposed.

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ECHO

Workplace based faecal occult blood screening

Please visit the *Occupational and Environmental Medicine* website [www.occenvmed.com] for a link to the full text of this article.

Population screening using faecal occult blood tests may increase the rate of detection of early stage colorectal tumours and reductions in mortality of 15%, 18%, and 33% have been shown in three large studies. Screening programmes based on general practices have had low rates of acceptance. It has been suggested that on-site health education might increase compliance rates in workplace based programmes, but a study at a large engineering company in the East Midlands, UK has also shown disappointing rates of compliance.

During 1992–93 a total of 1828 employees aged 41–65 were sent a letter explaining the study and inviting them to participate. Posters were put up at the site and the firm's medical department answered enquiries. Employees who agreed were sent a Haemoccult pack to provide samples for testing on three separate days. Positive tests were repeated after dietary restrictions (no red meat, black pudding, cauliflower, cabbage, spinach, radishes, parsnip, broccoli, or bananas) and, if still positive colonoscopy was offered. In all, 465 employees (25.4%) completed three Haemoccult tests. The rate of compliance was not significantly different between men (425/1703) and women (40/125). Men aged 51–60 were more likely to comply than men aged 41–50 or 61–65. Among women compliance rates were similar at ages 41–50 and 51–60. There were only seven women aged 61–65 and none of them completed a series of occult blood tests. Compliance was better among managers (28.6%) than non-managers (23.5%) especially in the youngest age group (41–50).

Four occult blood series (0.9%) gave a positive result and one remained positive after dietary restriction. This positive test led to the discovery of a 1 cm pedunculated polyp in the splenic flexure. After colonoscopic removal the tumour proved to be a tubular adenoma with mild dysplasia and complete excision margins. The financial cost of screening in 1993 was £6180 (testing kits £580, staff costs £5000, colonoscopy £600).

The uptake of screening in this company based programme was low and similar to that achieved in some general practice studies. More intense presentation of the case for screening might increase uptake but older and non-managerial employees might be the least likely to consent.

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