Aircraft Noise, Air Pollution, and Mortality From Myocardial Infarction

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Objective: Myocardial infarction has been associated with both transportation noise and air pollution. We examined residential exposure to aircraft noise and mortality from myocardial infarction, taking air pollution into account.

Methods: We analyzed the Swiss National Cohort, which includes geocoded information on residence. Exposure to aircraft noise and air pollution was determined based on geospatial noise and air-pollution (PM_{10}) models and distance to major roads. We used Cox proportional hazard models, with age as the timescale. We compared the risk of death across categories of A-weighted sound pressure levels (dB(A)) and by duration of living in exposed corridors, adjusting for PM_{10} levels, distance to major roads, sex, education, and socioeconomic position of the municipality.

Results: We analyzed 4.6 million persons older than 30 years who were followed from near the end of 2000 through December 2005, including 15,532 deaths from myocardial infarction (ICD-10 codes I 21, I 22). Mortality increased with increasing level and duration of aircraft noise. The adjusted hazard ratio comparing ≥60 dB(A) with <45 dB(A) was 1.3 (95% confidence interval = 0.96–1.7) overall, and 1.5 (1.0–2.2) in persons who had lived at the same place for at least 15 years. None of the other endpoints (mortality from all causes, all circulatory disease, cerebrovascular disease, stroke, and lung cancer) was associated with aircraft noise.

Conclusion: Aircraft noise was associated with mortality from myocardial infarction, with a dose-response relationship for level and duration of exposure. The association does not appear to be explained by exposure to particulate matter air pollution, education, or socioeconomic status of the municipality.

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Effects on the cardiovascular system have been reported for acute and chronic noise, occupational and residential exposure, and different types of noise—in particular, noise from aircraft and roads.[1–5] Reported health effects for chronic exposure include, for example, hypertension,[6,7] myocardial infarction,[5] cardiovascular morbidity or mortality,[2,8] and increased use of medication for cardiovascular conditions.[9]

Air pollution has also been recognized as a potential risk factor for adverse cardiovascular outcomes, including myocardial infarction.[10,11] Road traffic is an important source of both noise and air pollution, which makes it difficult to disentangle their independent associations with cardiovascular events. Indeed, measures of noise and air pollution from roads are often highly correlated.[2,12–14] Several investigators have called for studies that simultaneously examine effects of air pollution and noise,[15–17] but few such studies have been performed.[2,5,9]

The correlation with air pollution is considerably weaker for noise from aircraft than from roads, which should facilitate controlling for air pollution when examining the effects of noise. We used the data of the Swiss National Cohort[18,19] to examine the association between aircraft noise and mortality from myocardial infarction and selected other causes, taking levels of air pollution into account.

METHODS

Study Population

The Swiss National Cohort links the national census with mortality and emigration records using deterministic and probabilistic record linkage.[18] The present analysis was based on the 4 December 2000 census data and on mortality and emigration data for the period 5 December 2000 to 31 December 2005, with causes of death coded according to the 10th revision of the International Classification of Diseases, Injuries and Causes of Death (ICD-10). Enumeration in the 2000 census is near-complete; coverage was estimated at

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98.6%.[20] In persons older than 30 years, 95% of deaths could be successfully linked to a 2000 census record. We excluded persons younger than age 30 years, for whom linkage is less complete.[18] We also excluded people with missing building coordinates because these coordinates were necessary to determine exposure.

The database contains information on age, sex, marital status, and education. There are also variables at the level of the municipality and residential building, describing, for example, the degree of urbanization and socioeconomic characteristics of the municipality, the age of the house and whether it had been renovated. The geocoded places of residence are also included in the census data. In general, these coordinates give a location within a few meters of the building midpoint. Data of the census of 1990 were used to identify the place of residence at that time. The censuses of 2000 and of 1990 also include information on whether persons had lived at the same place 5 years before each census, ie, in 1995 or in 1985. We were thus able to identify persons who had lived at the same place for at least 5, 10, or 15 years. The Cantonal ethics committees of Bern and Zurich approved the Swiss National Cohort.

Outcomes

Outcomes were death from acute myocardial infarction and deaths from all circulatory diseases (regardless of whether the cause of death was listed as primary or concomitant cause on the death certificate) and deaths from all causes. We also considered cancer of the trachea, bronchus or lung as an indication of smoking behavior, and stroke, which is related to hypertension. Table 1 lists the ICD-10 codes of the causes of death analyzed.

Exposure to Aircraft Noise

There are 65 civil airports and airfields in Switzerland. For the largest airport, Zurich, a dedicated noise exposure model describes yearly average exposures for the years 2001–2005 in 1 dB(A) steps and a resolution of 100 × 100 m for day (6 AM–10 PM) and night exposure for the "first hour of the night" (10 PM–11 PM), "second hour of the night" (11 PM–midnight), and the rest of the night (only the airports of Zurich, Geneva, and Basle have air traffic after 10 PM). The model from the Federal Office of Civil Aviation was used for the other 64 airports (the 2 national airports in Basle and Geneva, 11 regional airports, and 51 smaller airfields). The model includes isophones in 5 dB(A) categories. We used L_{DN}A-weighted sound pressure levels, ie, time-weighted energy based means calculated from day (6 AM–10 PM) and night (10 PM–6 AM) sound pressure levels. In this calculation, night sound pressure levels receive a 10 dB(A) penalty,[21] as previously applied by others.[2,5,9,22] We analyzed exposure in 5 dB(A) categories (<45, 45–49, 50–54, 55–59, and ≥60 dB(A)).

Exposure to Air Pollution

We analyzed individual levels of exposure to background air pollution concentration at the place of residence, using a dispersion model for PM_{10} developed by the Federal Office for the Environment for the year 2000.[23,24] The models have a resolution of 200 × 200 m. The average exposure (in $\mu g/m^3$) at the place of residence was used in the analysis. As a proxy for traffic-related air pollutants, we also considered the proximity of the place of residence to the "major road network" and the "interconnecting road network," using data from the Swiss TeleAtlas database. The major road network includes motorways, slip roads, and other roads of high importance. The "interconnecting road network" describes main roads between towns and main traffic connections within the larger cities. We used corridors of <50, 50–99, 100–199, and ≥200 m around these roads.

Statistical Analyses

We analyzed the association between aircraft noise and cardiovascular mortality using Cox proportional hazard models, with age as the underlying timescale. Time was measured from the date of birth, with delayed entry: participants entered the risk set on the 5th of December, the day after the national census. Follow-up time was censored on the earliest of emigration, death from a cause other than the outcome, or 31 December 2005. Person-years of observation were calculated as the interval between 5 December 2000 and death, emigration or 31 December 2005. We compared the risk of death across exposure categories and by the duration of living in exposed corridors (for at least 5, 10, or 15 years). Noise

TABLE 1. ICD-10 Codes, Total Number of Deaths, and Number of Deaths in People Who Lived >15 Years at the Same Residence. Swiss National Cohort Study, 5 December 2000 to 31 December 2005

Cause of Death	ICD-10 Codes	No. Deaths Included in Analysis	No. Deaths in People Who Lived >15 Years at the Same Residence
Acute myocardial infarction	I 21, I 22	15,532	8192
All circulatory disease	I 00–I 99	177,836	86,999
Cancer of the trachea, bronchus or lung	C 33, C 34	14,095	7415
Stroke	I 60–I 64 (excluding I 63.6)	25,231	12,102

ICD-10 indicates 10th revision of the International Classification of Diseases, Injuries and Causes of Death.

TABLE 2. Characteristics of Study Population (n = 4.6 million) by Aircraft Noise and Air Pollution Categories

Exposure	Total Study Population %	Women %	Age (Years) Median	Tertiary Education %	Unemployed %	Foreign Nationals %	Old Building, Not Renovated %[a]
Aircraft noise (dB(A))							
<45	91.4	52	50.7	19	2	17	26
45–49	3.5	52	50.7	20	3	21	25
50–54	2.9	52	50.2	18	3	25	30
55–59	1.9	51	49.7	20	3	26	27
≥60	0.3	49	49.1	16	4	30	30
Distance to main road (m)							
≥200	17.2	52	51.2	21	2	12	21
100–199	23.4	53	50.9	21	2	16	23
50–99	23.6	53	50.6	20	2	18	26
<50	35.8	52	50.2	17	3	22	29
PM_{10}[b] (per 10 $\mu g/m^3$)							
<18.8	50.0	52	50.5	18	2	13	21
18.8–39.7	40.0	53	50.9	20	3	21	29
≥39.8	10.0	53	50.5	22	4	28	38

[a]Persons living in a building older than 30 years that had never been renovated.
[b]Cut-offs correspond to median and 90th percentile.

exposure below 45 dB(A) was used as the reference category. We tested models for the proportionality assumption using statistical tests based on Schoenfeld residuals; the assumption was met for all exposure variables.

Models were adjusted for sex (model I), sex and demographic, socioeconomic and geographical variables (model II), and additionally for air-pollution levels (PM_{10}) and distance to major roads (model III). These variables included civil status (single, married, divorced, widowed), nationality (Swiss, other), educational level (primary, secondary, tertiary), setting (urban, rural), language region (German, French, Italian), type of building (older than 30 years without renovation vs. other), and socioeconomic status of the municipality (Sotomo Index[25]). Using the fully adjusted model (model III), we performed stratified analyses by age (30–72.8, 72.9–82.3, >82.3 years, corresponding to the 33.3rd and 66.6th percentiles of age at death for myocardial infarction), sex, duration of living at the place of residence (at least 5, 10, or 15 years), and whether the building was old without having undergone major renovation work (30 years or older). We tested for interaction between these variables and the effect of exposure to aircraft noise by comparing models with and without interaction terms using likelihood ratio tests. Data were analyzed in Stata (version 10, Stata Corporation, College Station, TX). Results are presented as hazard ratios (HRs) with 95% confidence intervals (CI).

RESULTS

Of 7.29 million persons recorded in the 2000 census, 2.59 million (36%) were excluded because they were younger than 30 years at the census. Another 113,855 persons (2%) were excluded because of missing building coordinates. The analyses were based on 4,580,311 people, 22,512,623 person-years, and 15,532 deaths from acute myocardial infarction. The number of deaths from the other causes is given in Table 1; 282,916 people died of any cause.

Table 2 shows the characteristics of the study population by aircraft-noise and air-pollution categories. With increasing exposure to noise, the proportion of persons with tertiary education declined, whereas the proportion unemployed, the proportion of foreign nationals, and the proportion of people living in old and unrenovated buildings increased. Similar trends were seen with decreasing distance to major roads and increasing PM_{10} values.

Table 3 gives the results from the Cox regression models for death from acute myocardial infarction and from all circulatory disease. The risk of death from myocardial infarction was higher in people exposed to aircraft noise of 60 dB(A) or more. The association became stronger when models were adjusted for sociodemographic and geographical variables and PM_{10} air pollution levels, with the strongest association being observed in the fully adjusted analysis restricted to persons who had been exposed for 15 years or longer (HR = 1.5 [95% CI = 1.0–2.2]). Figure 1 shows fully adjusted HRs of death from myocardial infarction across exposure to aircraft noise, stratified by duration of exposure at the same place of residence; the increase in the risk of death from myocardial infarction became stronger with both increasing level and increasing duration of exposure. The risk of death from myocardial infarction was also higher in those living near a major road (<100 m). This association was again strongest in the fully adjusted

TABLE 3. Risk of Death From Selected Causes by Aircraft Noise and Air Pollution Exposure Categories, Switzerland, 2000–2005

	Hazard Ratios (95% Confidence Intervals)			
Exposure	**Model I**	**Model II**	**Model III**	**Model III Subpopulation[a]**
Acute myocardial infarction				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	0.96 (0.87–1.04)	1.00 (0.91–1.10)	1.02 (0.93–1.12)	1.03 (0.90–1.17)
50–54	0.97 (0.88–1.07)	1.01 (0.91–1.11)	1.02 (0.92–1.13)	1.05 (0.91–1.21)
55–59	0.98 (0.86–1.11)	1.04 (0.91–1.18)	1.05 (0.92–1.19)	1.14 (0.96–1.37)
≥60	1.27 (0.94–1.71)	1.28 (0.95–1.73)	1.30 (0.96–1.76)	1.48 (1.01–2.18)
Distance to major road (m)				
≥200	1.00	1.00	1.00	1.00
100–199	0.97 (0.92–1.02)	0.98 (0.93–1.04)	0.99 (0.94–1.04)	1.02 (0.95–1.10)
50–99	1.07 (1.02–1.12)	1.08 (1.03–1.14)	1.09 (1.03–1.15)	1.18 (1.10–1.27)
<50	1.10 (1.05–1.15)	1.10 (1.05–1.15)	1.10 (1.05–1.16)	1.17 (1.09–1.24)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	0.98 (0.97–0.99)	0.99 (0.97–1.00)	0.98 (0.97–1.00)	0.99 (0.97–1.01)
All circulatory disease				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	1.06 (1.03–1.09)	1.03 (1.00–1.05)	1.02 (0.99–1.04)	1.04 (1.00–1.08)
50–54	0.96 (0.93–0.99)	1.01 (0.97–1.04)	1.00 (0.97–1.03)	1.04 (0.99–1.09)
55–59	0.93 (0.89–0.97)	1.01 (0.97–1.06)	1.01 (0.97–1.05)	0.98 (0.92–1.04)
≥60	1.03 (0.92–1.14)	1.00 (0.90–1.11)	0.99 (0.89–1.09)	1.03 (0.89–1.18)
Distance to major road (m)				
≥200	1.00	1.00	1.00	1.00
100–199	1.00 (0.99–1.02)	1.02 (1.00–1.03)	1.02 (1.00–1.03)	0.99 (0.97–1.01)
50–99	1.01 (1.00–1.03)	1.04 (1.02–1.05)	1.04 (1.02–1.05)	1.03 (1.00–1.05)
<50	1.01 (1.00–1.03)	1.04 (1.03–1.06)	1.04 (1.03–1.06)	1.06 (1.04–1.08)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	1.00 (1.00–1.01)	1.00 (0.99–1.00)	1.00 (0.99–1.00)	1.00 (1.00–1.01)
Cancer of the trachea, bronchus, or lung				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	0.91 (0.83–1.00)	0.92 (0.84–1.02)	0.85 (0.77–0.94)	0.81 (0.70–0.93)
50–54	1.07 (0.97–1.18)	1.06 (0.96–1.17)	1.02 (0.93–1.13)	0.97 (0.85–1.12)
55–59	1.01 (0.89–1.14)	1.04 (0.92–1.18)	1.02 (0.90–1.16)	1.03 (0.87–1.23)
≥60	1.09 (0.80–1.48)	1.13 (0.83–1.53)	1.01 (0.74–1.37)	0.79 (0.48–1.29)
Distance to major road (m)				
≥200	1.00	1.00	1.00	
100–199	1.12 (1.06–1.18)	1.10 (1.04–1.17)	1.09 (1.03–1.15)	1.05 (0.98–1.13)
50–99	1.19 (1.13–1.26)	1.16 (1.09–1.22)	1.13 (1.07–1.19)	1.06 (0.99–1.15)
<50	1.29 (1.23–1.36)	1.22 (1.16–1.28)	1.19 (1.13–1.25)	1.10 (1.03–1.18)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	1.05 (1.04–1.06)	1.05 (1.04–1.07)	1.05 (1.03–1.06)	1.05 (1.03–1.07)
Stroke				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	0.99 (0.92–1.06)	0.96 (0.89–1.03)	0.97 (0.90–1.04)	1.03 (0.92–1.14)
50–54	0.94 (0.87–1.02)	0.96 (0.89–1.05)	0.97 (0.89–1.05)	1.02 (0.90–1.15)
55–59	1.01 (0.91–1.12)	1.06 (0.95–1.17)	1.06 (0.95–1.18)	0.96 (0.82–1.13)
≥60	0.84 (0.62–1.15)	0.82 (0.60–1.11)	0.83 (0.61–1.13)	0.88 (0.58–1.34)
Distance to major road (m)				
≥200	1.00	1.00	1.00	1.00
100–199	1.00 (0.97–1.05)	1.02 (0.98–1.06)	1.02 (0.98–1.06)	0.97 (0.91–1.03)
50–99	0.97 (0.93–1.01)	0.99 (0.95–1.03)	0.99 (0.96–1.04)	0.98 (0.92–1.04)
<50	0.99 (0.96–1.03)	1.01 (0.98–1.05)	1.02 (0.98–1.06)	1.03 (0.98–1.09)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	0.99 (0.98–0.99)	0.99 (0.98–1.00)	0.99 (0.98–1.00)	0.99 (0.97–1.00)

Model I, adjusted for sex, using age as the underlying time scale (all models).

Model II, adjusted for sex, civil status (single, married, divorced, widowed), nationality (Swiss, other), educational level (primary, secondary, tertiary), setting (urban, rural), language region (German, French, Italian), type of building (older than 30 years without renovation versus other), and socioeconomic status of the municipality.

Model III, adjusted for the same variables as in model II and all 3 exposure variables (noise, distance, PM_{10}) in the same model.

Major roads include motorways, slip roads, and main roads between towns and main traffic connections within the larger cities.

[a]Model III, analysis restricted to persons who lived at least 15 years at the same place of residence.

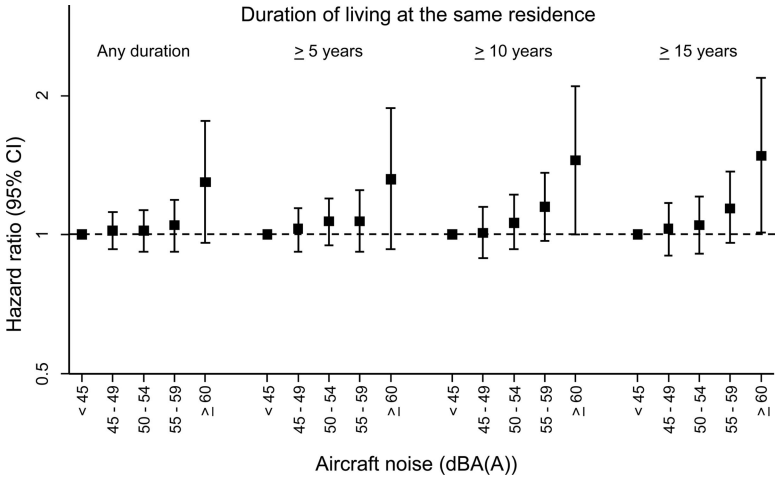

FIGURE 1. Mortality from myocardial infarction and estimated exposure to aircraft noise, Switzerland, 2000–2005. Results from model III are shown for persons who at the time of census had lived in the same place of residence for any duration, or for at least 5, 10, or 15 years.

model, restricted to people who had been exposed for at least 15 years (Table 3). No association was seen with increasing concentrations of PM_{10}.

The risk of death from all circulatory disease was not associated with aircraft noise or levels of PM_{10}, although it was slightly increased near major roads (Table 3). Similarly, mortality from cancer of the trachea, bronchus, or lung was not increased in those exposed to high levels of aircraft noise, but it was increased among people living close to a major road and among people exposed to high levels of PM_{10}. The association with distance to major roads was attenuated when adjusted for sociodemographic and geographical variables. No associations were observed with the risk of death from stroke (Table 3). Finally, there was little evidence for an association with mortality from all causes, in either sex-adjusted or fully adjusted analyses. The HR comparing ≥60 dB(A) with <45 dB(A) for death from all causes from the fully adjusted analysis (model III) was 1.0 (95% CI = 0.96–1.1).

Results were similar in sensitivity analyses when considering day-time or night-time exposures rather than time-weighted energy-based means (data not shown). Fully adjusted HRs from model III comparing highest (≥60 dB(A)) with lowest (<45 dB(A)) levels of exposure to aircraft noise tended to increase with increasing age, and were higher in men compared with women. Noise exposure was also higher for people living in old buildings that had not been renovated compared with new or renovated buildings (Fig. 2). Formal tests of interaction, however, failed to reach conventional levels of statistical significance ($P > 0.32$).

Additional information is provided in 2 supplementary online tables. eTable 1 (http://links.lww.com/EDE/A426) shows the distribution of person-years and deaths in each exposure category. eTable 2 (http://links.lww.com/EDE/A426) gives Pearson correlation coefficients showing that daytime exposure ($L_{Aeq,\ day}$) was correlated with $L_{Aeq,\ night}$ and with L_{DN} exposure. Correlation between aircraft noise and distance to roads or PM_{10} levels was weak, with Spearman rank correlation coefficients ranging from 0.01 to 0.22.

DISCUSSION

This large national linkage study found that people exposed to high levels of noise from aircraft were at increased risk of dying from myocardial infarction. The association was strongest in those who had lived at the same highly exposed location for at least 15 years. We found no association of fatal myocardial infarction with levels of background PM_{10} levels, although the risk of death from myocardial infarction was higher among persons living near a major road. The strength of the association between aircraft noise and death from

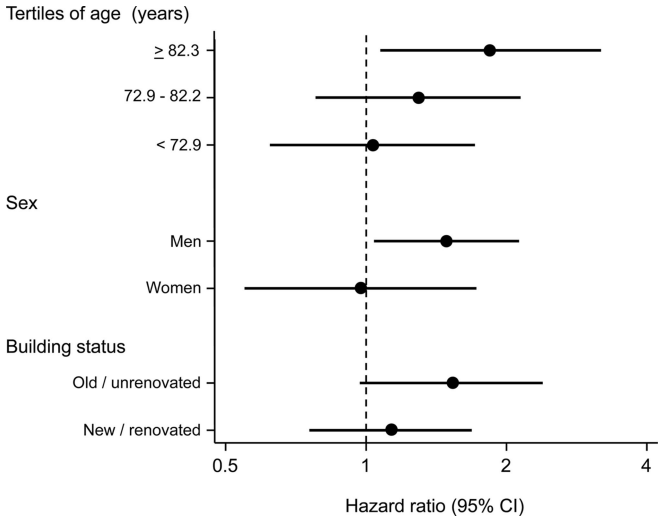

FIGURE 2. Mortality from myocardial infarction comparing highest (≥60 dB(A)) with lowest (<45 dB(A)) levels of exposure to aircraft noise, stratified by age, sex, and status of building. Results from model III are shown for persons who at the time of census had lived in the same place of residence for any duration.

myocardial infarction was not attenuated when the analysis was adjusted for distance to major roads and for levels of PM_{10}. As expected, the correlation of aircraft noise with the other 2 exposures was weak, which made it possible to include all 3 variables in the multivariable model. Finally, there was little evidence of an association between aircraft noise and all circulatory diseases.

Confounding by lifestyle factors associated with socioeconomic position is of concern, as we observed that living in highly exposed areas in the vicinity of airports was associated with lower educational level. Earlier analyses of the Swiss National Cohort found substantial educational gradients in mortality and life expectancy; life expectancy at age 30 was 7 years greater in men with university education compared with men who had compulsory education only.[18,26] It is therefore noteworthy that statistical adjustment for educational level and other variables related to socioeconomic position at the level of the building and community did not affect the strength of the association between exposure to aircraft noise and mortality from myocardial infarction. Also, no association emerged between mortality from all causes and exposure to aircraft noise, both in sex-adjusted and maximally adjusted analyses. Taken together, it thus seems unlikely that the association is explained by factors associated with lower education and socioeconomic position in those exposed to aircraft noise.

The Swiss National Cohort combines 2 population registers that are virtually complete: the national census and national routine mortality data. This, in combination with the use of dispersion models rather than individual measurements to assess exposure, essentially excludes bias due to selective participation. The use of dispersion models may, however, have introduced exposure misclassification; a person's exposure to aircraft noise will be modified by building characteristics as well as lifestyle factors. Such misclassification will probably be nondifferential, and is unlikely to explain the increased mortality we observed for myocardial infarction but not for other causes of death. Incomplete linkage of deaths might also have introduced bias. Most deaths (95%) could be linked to a census record, but results could have been distorted if the completeness of death linkage was itself related to noise exposure. Foreign nationals were more common among those exposed to high levels of aircraft noise, and linkage rates were slightly lower in foreign than in Swiss nationals (92% compared with 95%). Studies from New Zealand and Northern Ireland found that deaths in socioeconomically disadvantaged persons were less likely to be successfully linked to a census record.[27,28] We cannot directly examine this in the Swiss cohort due to missing data on socioeconomic position on the death certificate, but such bias is also likely in our study. Under-ascertainment of deaths in highly exposed people, which would have biased results toward the null, is therefore more likely than over-ascertainment of deaths.

Bias in coding of deaths must also be considered. If the probability of recording myocardial infarction, lung cancer, or stroke on the death certificate was affected by exposure status, bias could be introduced. Such cause of death attribution bias was, for example, observed in a sample of US death certificates: compared with data from a cohort study in the same population, lung cancer was less likely to be recorded as the underlying cause if the decedent had never smoked, and more likely to be recorded as an underlying cause if the person who died was a smoker.[29] Such bias is, however, unlikely in studies of aircraft noise.

What mechanisms other than confounding and bias might be at work? Exposure to high levels of aircraft noise could increase levels of psychologic stress, leading to hypertension and ultimately increasing the risk of death from ischemic heart disease.[30] Hypertension and psychosocial factors, including perceived stress and depression, may account for a substantial proportion of the risk of myocardial infarction worldwide.[31] Higher levels of stress may also be related to smoking.[32] A review of the literature on stress hormones and noise concluded that there were unequivocal effects of noise exposure on the endocrine system, but that it was unclear whether the findings from experimental studies translated into health hazards.[33] More recently a substudy of the Hypertension and Exposure to Noise near Airports project, a multicenter cross-sectional study in 6 European countries, found that morning saliva cortisol levels tended to be increased in people exposed to aircraft noise.[34] In the main study,[7] night-time exposure to aircraft noise increased the risk of hypertension. We found no association between exposure to aircraft noise and mortality from stroke, which is closely related to hypertension. Similarly, we found no association with mortality from lung cancer, which is closely related to smoking.

We also observed an increased risk of myocardial infarction in people living close to a major road ($<$100 m) but no association with background PM_{10} levels. Exposure to high levels of road traffic noise might explain this finding, but the lack of data on road traffic noise is a limitation of our study. A national noise database suitable for reliably assigning traffic noise levels to individuals is in development in Switzerland.[35] Alternatively, the increased risk associated with living near a major road might be related to high levels of ultrafine particles. In a Dutch cohort study,[36] cardiopulmonary mortality was more strongly associated with locally generated pollutants than with background air-pollution levels.

Several recent reviews and meta-analyses have examined the association between transportation noise exposure and cardiovascular outcomes.[1,30,37] In 2002, Van Kempen et al[30] concluded that the evidence for an association was inconclusive because of limitations in exposure characteriza-

tion, lack of adjustment for important confounders, and possible publication bias. More recently, Babisch[1,37] argued that the evidence for an association between transportation noise and cardiovascular risk has become stronger in recent years, with a consistently increased risk of ischemic heart disease in those exposed to aircraft or road traffic noise above 60 dB(A). Previous studies also found duration of exposure to be relevant, with higher risks in persons having been exposed at least 10 to 15 years.[38,39] Although the majority of transportation-noise studies have excluded women, there is some evidence that sex could modify effects.[37] We found increased risks in men but not in women, confirming results from some[7,38] but not all previous studies.[2,5] Our stratified analyses also suggest that effects might depend on building characteristics; low levels of insulation against noise in old buildings that had not been renovated could explain the higher risk observed in their inhabitants. For all stratified analyses, formal tests of interaction failed to reach conventional levels of statistical significance.

In conclusion, our study adds to a growing body of evidence supporting a link between high levels of exposure to aircraft noise over extended periods of time and mortality from myocardial infarction. It is unlikely that our results are explained by confounding by socioeconomic position in those exposed to aircraft noise. If the association is causal, the mechanisms that may be involved are unclear. When examining mortality from stroke or lung cancer, we found no indirect evidence supporting the hypothesis that hypertension or smoking might act as intermediate factors on the causal pathway. Cardiovascular risk factors were not assessed in this large linkage study, and therefore, we could not examine their possible role in mediating or confounding the association between aircraft noise and myocardial infarction.

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