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Aircraft noise exposure and objective sleep quality in the population living near airports in France

Ali-Mohamed NASSUR^{a)}

Marie LEFÈVRE

Anne-Sophie EVRARD

Univ Lyon, Université Claude Bernard Lyon1, IFSTTAR, UMRESTTE, UMR T_9405, Bron, France

Maxime ELBAZ

Damien LÉGER

Université Paris Descartes, APHP, Hôtel-Dieu de Paris, Centre du Sommeil et de la Vigilance et EA 7330 VIFASOM, Paris, France

Fanny MIETLICKI

Philippe NGUYEN

Carlos RIBEIRO

Matthieu SINEAU

Bruitparif, Noise Observatory in Ile de France, Paris, France

Bernard LAUMON,

IFSTTAR, Transport, Health and Safety Department, Bron, France

ABSTRACT

Background: Aircraft noise has been shown to have adverse effects on health and particularly on sleep. The aim of the study was to investigate the association between aircraft noise exposure and objective sleep quality in the population living near airports in France.

Methods: Actimetric measurements were performed during eight nights to evaluate sleep quality of 112 participants in terms of total sleep time (TST), sleep onset latency (SOL), wake after sleep onset (WASO) and sleep efficiency (SE). Simultaneously, acoustic measurements were performed inside and outside (at the façade) the participants' bedroom

^{a)} ali-mohamed.nassur@ifsttar.fr

in order to estimate integrated indicators as well as the number of noise events. Logistic regression models were used with adjustment for potential confounders.

Results: Integrated indicators as well as the number of noise events were significantly associated with objective sleep quality: increased levels or numbers of aircraft noise events increased SOL and total WASO, and decreased SE. Unexpectedly, they were also associated with an increased TST. We hypothesized an adaptation mechanism to sleep deprivation.

Conclusion: Noise event indicators have been shown to be more often associated with sleep disturbances than integrated indicators.

1 INTRODUCTION

Transportation noise is a major source of environmental noise pollution, and it represents a major public health issue. According to the World Health Organization (WHO), transportation noise is estimated to cause at least one million healthy life years lost every year in Western Europe, and sleep disorders are the most serious consequence with more than 900 thousand years of life lost every year, mostly related to road traffic noise ¹.

Near airports, aircraft noise is perceived as a major environmental stressor. It also constitutes a major issue for public health, particularly in terms of sleep disturbance ¹. Several studies have been conducted to assess the effect of aircraft noise on sleep. Aircraft noise has been shown to disrupt sleep. Exposure to night time aircraft noise leads to an increased frequency of awakening, increased motility, decreased slow wave sleep, changes in sleep structure, use of sleep drugs or sedatives, and a poor quality of sleep ².

Most studies conducted near airports have used integrated noise indicators, often estimated outside the dwellings using modelling software. However, according to a literature review by Michaud et al, indoor sound levels are more closely associated with sleep disturbance than outdoor measures ³. Moreover, noise event indicators are rather recommended because they could better characterize aircraft noise ⁴.

In this context, the aim of the present study was to investigate the association between measured both outdoor and indoor exposure to aircraft noise and objective sleep quality in the population living near airports in France. Noise integrated indicators (related to energetic average calculated on different periods of time) and noise event indicators were taken into account.

2 METHODS

In total, 112 individuals older than 18 and living near two major French airports agreed to participate in the study: 92 participants around Paris-Charles de Gaulle airport and 20 around Toulouse-Blagnac airport. These subjects were selected after an interview with an investigator at their home as part of the DEBATS longitudinal study ⁵.

2.1 Assessment of aircraft noise exposure

Aircraft noise exposure was assessed based on acoustic measurements performed outside and inside the bedroom of each participant. The measurements have been carried out for eight days in order to cover the different activities of the airport. Two sonometers were placed in the subjects' dwellings in order to collect accurate and reliable data on the acoustic impact of aircraft overflights in the bedroom. The first sonometer located in the participants' bedroom recorded their noise exposure at night. The second sonometer set up outside (at the bedroom façade) allowed us to identify the aircraft noise and to evaluate the impact of this noise in the participants' bedroom. Bruitparif (Noise Observatory of the Paris region), partner of the DEBATS project, developed an algorithm allowing us to derive the noise level from aircraft only inside the bedroom.

Based on these measurements, integrated noise indicators (related to energetic average calculated on different periods of time) and noise event indicators were estimated during the sleep period, that is between sleep onset and final awakening. Among integrated noise indicators, the equivalent continuous sound pressure level (LAeq) inside (LAeq,int) and outside (LAeq,ext) of the bedroom have been calculated. Among the noise event indicators, the total number of aircraft noise events inside (NA,int) and outside (NA,ext) of the bedroom have been determined.

2.2 Assessment of objective sleep quality

A wrist-worn actigraph, Motionwatch 8 (CamNtech Ltd), was used in order to evaluate objective sleep quality of the participants. Measurements, from both actigraph and sleep diary, were performed for eight consecutive days, the same eight days as those of acoustic measurements. These two measures allow the identification of objective and accurate sleep quality. Actigraph records movements during sleep that can be used to estimate sleep parameters with specialized algorithms in computer software programs. Some parameters related to sleep schedules (beginning, end, duration) can then be assessed. The following sleep parameters were derived from the actigraph measurements: sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO) and sleep efficiency (SE). These parameters were dichotomized in order to be linked to aircraft noise exposure. $SOL \geq 30$ minutes, $TST < 6$ hrs, $WASO \geq 30$ min and $SE < 90\%$ can be considered as insomnia characteristics.

2.3 Statistical analysis

Logistic regression models with repeated measurements were used in order to estimate the relationship between aircraft noise exposure and objective sleep quality. The following potential confounders were taken into account in the models: age, gender, marital status, education and body mass index (BMI).

3 RESULTS

Almost 58% of the participants in our study were women and near half of the participants were married (Table 1). Nearly 45% of participants had sleep latency greater than 30 minutes. 18% slept less than 6 hours per night, 35% have a wake time after sleep onset higher than 30 minutes and 13% have a poor sleep efficiency.

Table 1 - Description of the study population

	n	(%)
Gender		
Women	65	58
men	47	42
Age		
18-34	32	29
35-44	19	17
45-54	27	24
55-64	17	15
65-74	9	8
75+	8	7
Marital status		
Single	39	35
Married	53	47
Widowed	4	4
Divorced	16	14
Education		
< French high school certificate	39	35
French high school certificate	37	33
> French high school certificate	36	32
BMI		
Underweight or normal weight	58	52
Overweight	41	37
Obesity	13	12
<i>Sleep parameters</i>		
SOL \geq 30 min	50	45
TST < 6hr	20	18
WASO \geq 30 min	39	35
SE < 90	14	13

During the sleep period, the equivalent continuous aircraft noise level was 47 dB(A) outside the bedroom and 18 dB(A) inside the bedroom (Table 2). The number of aircraft noise events was 37 outside the bedroom and 29 inside the bedroom.

Table 2. Description of noise indicators

	Mean	SD	P5	P95
Integrated noise indicators				
LAeq,ext	47	8	30	58
LAeq,int	18	8	3	32
Noise events indicators				
N,ext	37	36	0	99
N,int	29	30	0	84

The Odds-Ratios (ORs) and their 95% confidence intervals (CIs) for objective parameters of sleep quality in relation to aircraft noise exposure are presented in Table 3. A significant positive association was found between both integrated aircraft noise indicators and both aircraft noise event indicators and TST: an increase in the aircraft noise level or in the number of aircraft noise events, outside and inside the bedroom, decreased the probability of sleeping less than 6 hours. A positive and significant association was also found between both integrated indicators, outside and inside the bedroom, and SOL. The association was even higher inside the bedroom: a 10 dB(A)-increase in the equivalent continuous noise level inside the bedroom (LAeq, int) was associated with an increase in SOL with an OR of 1.45 (95% CI: 1.12-1.88). A positive and significant association was found between noise event indicators, outside and inside the dwellind, and WASO: an increase of 10 aircraft noise events inside the bedroom was associated with an increase in the total duration of waking time after sleep onset with an OR of 1.11 (95% CI: 1.01-1.22). ORs between acoustic indicators and sleep efficiency indicated deterioration in sleep efficiency related to an increase in the level or number of aircraft noise events. However, these associations were not significant.

Table 3 - Odds ratios for the relationship between noise indicators and objective sleep parameters.

	SOL ≥ 30 min	TST < 6 hr	WASO ≥ 30 min	SE < 90
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Noise indicators				
LAeq,aero,ext ¹	1.26 (1.01-1.57)	0.56 (0.42-0.74)	1.07 (0.77-1.49)	1.20 (0.82-1.76)
LAeq,aero,int ¹	1.45 (1.12-1.88)	0.59 (0.46-0.76)	1.13 (0.82-1.57)	1.26 (0.86-1.85)
Noise events indicators				
N,ext ²	1.02 (0.96-1.08)	0.69 (0.63-0.76)	1.11 (1.04-1.18)	1.06 (0.99-1.14)
N,int ²	1.04 (0.97-1.11)	0.69 (0.62-0.76)	1.11 (1.01-1.22)	1.07 (0.98-1.16)

¹Per 10 dBA increase

²Per 10 events increase

Bold values are statistically significant $p \leq 0.05$

4 DISCUSSION

The present study investigated the effects of aircraft noise exposure on objective sleep quality evaluated with an actigraph in the vicinity of French airports (Paris-Charles de Gaulle and Toulouse-Blagnac). Objective sleep quality was characterized through four parameters: SOL, TST, WASO and SE. The prevalence of short sleepers (TST < 6 hours) estimated in this study was similar to the one estimated in 2010 in the Health Barometer survey (18%) for the French population ⁶.

The present study confirms in the results of most studies in the literature: aircraft noise exposure leads to an increase in SOL and WASO ^{7,8}. However in contrast to most studies that found a decrease in TST associated to transportation noise exposure ⁹, this study showed an increased TST. We hypothesized that it could be an adaptation behavior to sleep deprivation. Individuals would stay longer in bed to try to sleep more and recover. A previous study in a laboratory also found an increased TST following exposure to aircraft noise ¹⁰. The authors also explained this result with adaptation mechanisms to partial sleep deprivation during previous nights exposed to noise ¹⁰.

Acoustic measurements were performed in the present study in order to estimate aircraft noise exposure not only in terms of integrated noise indicators but also in terms of noise event indicators, whereas almost all epidemiological studies on the subject used integrated indicators. However, noise event indicators are rather recommended because they could better characterize aircraft noise ⁴. Several indicators (not shown) have been calculated and event indicators were significantly associated with almost all the objective parameters of sleep quality studied, contrary to integrated indicators. This confirms the study by Griefahn and *al* which showed that energy indicators such as LAeq do not seem to be appropriate predictors for the quality of sleep evaluated objectively ¹¹. Ohrstrom and Rylander also showed that the number of road noise events had a significantly greater effect on objective and subjective sleep quality than continuous noise level ¹².

In the present study, acoustic measurements were performed outside and inside the bedroom. Acoustic indicators were associated with objective sleep parameters, whatever they were estimated outdoors or indoors. This result does not support the hypothesis of a literature review which states that aircraft noise levels measured indoors are more closely associated with sleep disturbances than levels measured outside buildings ³.

5 CONCLUSIONS

The findings of the present study contribute to the overall evidence suggesting that aircraft noise exposure at night-time may decrease objective quality of sleep. Adaptation mechanisms to sleep deprivation could be observed. Aircraft noise exposure affects objective parameters of sleep quality not only in terms of noise levels but also in terms of number of events. Noise event indicators have been shown to be more often associated with sleep disturbances than integrated indicators.

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