Aircraft noise exposure and saliva cortisol in the DEBATS longitudinal study

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ABSTRACT

Although aircraft noise is known to impact human health, the biological pathway is still unclear with a possible one being hormonal disturbance and the modification of the cortisol circadian rhythm.

This longitudinal study aimed to characterize the association between aircraft noise and cortisol.

A total of 1,115 participants living near three major French airports responded in 2013, 2015 and 2017 to detailed face-to-face interviews and collected two saliva samples: one after awakening and one before going to sleep. ELISA kits were used to determine cortisol levels in these samples. Outdoor noise levels were estimated at each home address using noise maps. Longitudinal analyses were performed using linear mixed model adjusted on potential confounders.

A 10 dB(A) increase in L_{den} levels was associated with decreased diurnal slope of cortisol (β=0.14; 95% confidence interval: 0.06-0.22), higher evening cortisol levels (exp(β)=1.16; 95% CI: 1.08-1.23) and decreased morning levels (exp(β)=0.95; 95% CI: 0.90-1.00).

In our longitudinal study, aircraft noise exposure was associated with flattened diurnal cortisol rhythm across the day, indicating a possible disruption of hypothalamus-pituitary-adrenal axis regulation. These findings confirm those based on the data collected in 2013 only.

INTRODUCTION

Although aircraft noise is known to impact human health, the biological pathway is still unclear. One possible pathway is hormonal disruption [1] with modification of the cortisol circadian rhythm. Cortisol is a hormone secreted by the adrenal gland and regulated by the hypothalamus-pituitary-adrenal (HPA) axis, which follows a circadian rhythm. Cortisol level is at its lowest level in the evening, rises during the night until awakening, which is shortly followed by a sharp increase called the cortisol awakening response (CAR) [2]. The HPA axis is a stress response system and cortisol levels can be altered in various stress-related pathologies [3].

The European HYENA study and the French DEBATS study [4–6] investigated the association between aircraft noise exposure and cortisol levels and observed a possible modification of the cortisol circadian rhythm.

This study aimed to characterize the association between aircraft noise and cortisol in the French DEBATS longitudinal study.

METHODS

Study population

Participants older than 18 were randomly selected by phone survey nearby three major French airports (Paris-Charles de Gaulle, Lyon-Saint Exupéry and Toulouse-Blagnac). The recruitment was stratified on four aircraft noise categories (<50 dB(A), 50-54 dB(A), 55-59 dB(A), ≥60 dB(A)) based on the day-evening-night equivalent level (L_{den}) estimated from noise maps (see exposure assessment). At baseline in 2013, 1,244 participants completed a detailed face-to-face interview at home [7]. They were asked to provide two saliva samples in test tubes (Sarstedt, Nümbrecht, Germany) with the sampling date and time. Participants were requested to collect one sample immediately after awakening and another one just before going to bed, in order to measure the cortisol diurnal slope [8].

The participants were contacted again in 2015 (first follow-up) and 2017 (second follow-up) to complete a follow-up questionnaire similar to the baseline one and provide saliva samples following the same protocol (see [4] for detailed procedure). Participants were included at each follow up if they provided both samples with sampling date and time, if there were less than 24h between the two samples and if they reported no known modifiers of their cortisol production or circadian rhythm (i.e. use of specific medications, shift workers, atypical sleeping or awakening times).

Exposure assessment

Aircraft noise exposure in terms of L_{den} was estimated in 1 dB(A) intervals for each participant with a linkage between the noise maps and their home address using a geographic information system (GIS) technique. If a participant moved between two interviews but stayed in the study area, aircraft noise exposure was also estimated at the new home address. A noise map produced with the Integrated Noise Model by Paris Airports from 2008 was used for Paris-Charles de Gaulle airport, while noise maps produced by the French Civil Aviation Authority from 2003 was used for Toulouse-Blagnac and from 2004 for Lyon-Saint Exupéry.

Study outcomes

For each participant and follow-up, morning salivary cortisol concentration, evening salivary cortisol concentration and diurnal slope (the difference between the evening and morning concentrations divided by the time between the two samples) were estimated. As the morning and evening concentration distributions were right skewed, a logarithmic transformation was applied.

Most of the participants at baseline (82%) and first follow-up (74%) and some at second follow-up (28%) performed the evening sampling first and the morning sampling later. To be able to estimate diurnal slope, we assumed that the awakening cortisol level from one day to the next remains stable. We thus estimated diurnal slope in these participants by the difference between the evening and morning concentrations divided by the difference between 24hours and the time between the two samples.

Statistical analyses

Longitudinal analyses were performed using logistic mixed models with subject-specific random intercept and adjusted on follow-up. Models were additionally adjusted on the following a priori selected confounders: age (continuous), gender (dichotomous), monthly household income (three categories: less than 2300€, between 2300 and 4000€, more than 4000€), body mass index (continuous), regular physical activity (dichotomous), smoking habits (four categories: non-smoker, former smoker, occasional smoker, daily smoker), alcohol consumption (four categories: none, light, moderate, heavy), the day of the week of the saliva sampling (two categories: weekday/weekend). Morning and evening concentration models were additionally adjusted for sampling time (four categories for morning: 4:30-6:30, 6:30-7:30, 7:30-8:30, 8:30-10:30 and three categories for evening: 20:30-22:30, 22:30-23:30, 23:30-1:30).

Sensitivity analyses were conducted by running the main adjusted regression models 1) excluding people who moved in the five years prior to baseline and 2) excluding lost to follow-up participants.

RESULTS

Study population

Among the 1,244 participants included in the study in 2013, 954 were included in the cortisol analyses. In 2015, 992 participants answered to the first followed-up questionnaire, with 786 included in the cortisol analyses and in 2017, 811 completed the second follow-up questionnaire, with 658 included in the cortisol analyses. Characteristics of the participants are available in Table 1.

At baseline, median morning cortisol level was 24.3 nmol/L (26.0 nmol/L at first follow-up and 13.0 nmol/L at second follow-up, respectively). Median evening cortisol level was 4.5 nmol/L (7.5 nmol/L at first follow-up and 2.1 nmol/L at second follow-up, respectively). Diurnal slope was -1.3 nmol/L/h (-1.1 nmol/L/h at first follow-up and -0.7 nmol/L/h at second follow-up, respectively) (Table 1).

Table 1: Description of the participants

Characteristics N (%)	**Baseline** (n=954)	**First follow-up** (n=786)	**Second follow-up** (n=658)
Airport			
Paris Charles de Gaulle	457 (48)	354 (45)	294 (45)
Toulouse Blagnac	317 (33)	284 (36)	236 (36)
Lyon Saint Exupéry	180 (19)	148 (19)	128 (19)
Gender			
Women	554 (58)	449 (57)	360 (55)
Men	400 (42)	337 (43)	298 (45)
Age			
(Median (5^{th}-95^{th} percentiles))	52 (25;77)	54 (29;78)	56 (31;78)
Morning cortisol level (nmol/L)			
(Median (5^{th}-95^{th} percentiles))	24.3 (6.3;48.0)	26.0 (7.7;60.2)	13.0 (2.6;36.8)
Evening cortisol level (nmol/L)			
(Median (5^{th}-95^{th} percentiles))	4.5 (1.4;20.8)	7.5 (2.3;30.4)	2.1 (0.6;12.7)
Diurnal slope (nmol/L/h)			
(Median (5^{th}-95^{th} percentiles))	-1.3 (-2.8;0.3)	-1.1 (-3.4;0.3)	-0.7 (-2.3;0.2)

Aircraft noise and cortisol

A 10 dB(A) increase in L_{den} levels was associated with a decrease in the diurnal slope of cortisol (β=0.14; 95% confidence interval 95% CI: 0.06-0.22), higher evening cortisol levels (exp(β)=1.16; 95% CI: 1.08-1.23) and decreased morning levels (exp(β)=0.95; 95% CI: 0.90-1.00). Results remained similar when sensitivity analyses were conducted for evening concentration and diurnal slope (results not shown). An increase in L_{den} was associated with a decrease in morning concentrations in the sensitivity analyses.

DISCUSSION

In our longitudinal study, aircraft noise exposure was associated with a flattening of the diurnal cortisol rhythm across the day, indicating a possible disruption of HPA axis regulation. These findings confirm those based on data collected in 2013 only [4] and are consistent with what was observed in HYENA [5] and HYENA+DEBATS [6] populations: altered cortisol levels were observed in subjects exposed to higher levels of aircraft noise.

Some limitations must be acknowledged. We cannot be sure that the participants collected their morning sample immediately after awakening. Thus it is possible that the morning concentration partly reflects the cortisol awakening response and not the baseline level only. In addition, we do not have any information on stressful events that may have occurred during the sampling day, potentially affecting the evening level. This could challenge our hypothesis that morning concentration is similar from one day to the next. Nevertheless, the number of participants included in this study is large, they were followed for four years, and a limited number of them were lost to follow-up.

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