14th ICBEN 2023 18 - 22 JUNE BELGRADE

14th ICBEN Congress on Noise as a Public Health Problem

# The effects of aircraft noise on sleep quality, sleepiness and annoyance in individuals sleeping during daytime vs. nighttime

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## *EXTENDED ABSTRACT*

### INTRODUCTION

Nighttime work is a vital factor for the functioning of modern societies [1]. Around 15 % of the population in Germany work night shifts, requiring them to sleep during the day [2]. Night workers often work between 23:00 and 07:00 h [3] and consequently have to sleep at daytime. Due to the circadian misalignment associated with shift work sleep is more fragile [4].

As ample evidence shows, environmental noise, including aircraft noise, can disturb sleep by increasing sleep fragmentation and reducing sleep depth [5]. Moreover, with increasing noise exposure, self-reported sleep quality decreases [5] and annoyance increases [6]. However, evidence exists mostly for the healthy population, whereas less is known about noise effects in vulnerable groups such as shift workers, the elderly and individuals with an illness who may be more susceptible to the adverse effects of noise [7].

Up to now, the effect of noise on daytime sleep has scarcely been investigated. Research on the specific effect of aircraft noise on daytime sleep is lacking completely. The present laboratory study examined the effect of aircraft noise exposure during both nighttime sleep and daytime sleep, with the latter serving as model for intrinsically more fragile sleep. To this end we quantified objective and subjective sleep quality, sleepiness as well as short-term annoyance.

### MATERIALS AND METHODS

In the present study, 33 participants (aged 18-40 years; 18 females) slept in the laboratory during two visits that included two consecutive sleep episodes, each. We assigned participants randomly to either a daytime sleep group (“day sleepers”) or a nighttime sleep group (“night sleepers”). The two laboratory visits, during one of which participants were exposed to aircraft

noise during both sleep episodes, were separated by a recovery break of at least seven days. During the sleep episodes with aircraft noise exposure, a noise scenario composed by 81 aircraft fly-over sounds from eight different aircraft types was played back in the bedrooms. The resulting energy-equivalent sound pressure level across the time in bed was $L_{eq}$ = 46.8 dB(A) representing a common indoor aircraft noise exposure near Cologne/Bonn Airport, which is a German hub with a 24/7 operation scheme. For the purpose of a typical aircraft noise scenario, we recorded aircraft sounds in an apartment with tilted windows located six km away from the airport and directly under the flight path.

We measured sleep via polysomnography and derived the following sleep parameters: Sleep efficiency, number of awakenings, time spent in sleep stages 1, 2 and slow wave sleep as well as REM sleep. Sleep quality was also assessed via self-reports using a six-item questionnaire.

After getting up, participants rated their acute sleepiness using the Karolinska Sleepiness Scale [8] and their annoyance due to aircraft noise using an adapted version of the 5-point verbal ICBEN scale [9]. Sleepiness assessments were repeated after 10 to 11 hours awake as well as shortly before the next sleep episode.

The effect of aircraft noise exposure on the selected criterion variables were analyzed separately in the daytime sleep and the nighttime sleep group using linear mixed models. We included noise exposure, sleep episode, and an interaction between noise exposure and sleep episode as predictors plus a random intercept for the participants.

## RESULTS

Results showed significant effects of aircraft noise exposure on subjective sleep quality and annoyance reported after getting up in both day and night sleepers. Sleepiness averaged across assessment times (after getting up, after 10/11 hours awake, prior to the next sleep episode) was significantly increased after sleep under aircraft noise exposure in day sleepers, but not in night sleepers.

An effect of aircraft noise exposure on sleep efficiency was found neither for night sleepers nor day sleepers. Time spent in sleep stages 1 and 2 was higher under noise exposure in day sleepers, but not in night sleepers. Likewise, the number of awakenings was increased during noise exposure in day sleepers, but not in night sleepers. Noise exposure reduced the time spent in REM sleep and slow wave sleep on a trend level ($p < 0.1$) during noise exposure in day sleepers, but not in night sleepers.

Besides, in day sleepers, an interaction between the noise exposure and the sleep episode was found such that slow wave sleep was reduced in the first but not in the subsequent sleep episode with noise exposure. On a trend level, an interaction between noise exposure and the sleep episode was found for the number of awakenings in day sleepers. Whilst the number of awakenings was higher in the first sleep episode with noise exposure, it was not in the second one. Similarly, we found an interaction for noise annoyance and subjective sleep quality in day sleepers. Annoyance was increased and self-rated sleep quality was decreased in the first noise-exposed sleep episode whilst noise exposure showed no effect in the subsequent sleep episode.

## DISCUSSION AND CONCLUSION

The present findings indicate a stronger effect of aircraft noise exposure on participants sleeping during daytime than on participants sleeping during nighttime. The data suggest that

intrinsically more fragile sleep of night workers may be more vulnerable to the effects of transportation noise.

The significant interactions between noise exposure and the sleep episode may indicate that a compensation takes place between the first and the second noise-exposed sleep episode in day sleepers. The loss in slow wave sleep and the higher number of awakenings seem to have activated homeostatic compensatory mechanisms that prevented effects of noise exposure to become manifest during and immediately after the second sleep episode. Lower annoyance scores and higher subjective sleep quality given after the second sleep episode may reflect the assumed compensatory response.

Since the current study investigated the effects of aircraft noise exposure on people who are required to sleep during daytime for the first time, a discussion of the results in the light of previous findings is hardly feasible. However, the current findings warrant further examination of the effect of transportation noise on sleep in night workers, preferably across a longer time span.

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