PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Effects of nocturnal aircraft noise on objective and subjective sleep quality in primary school children

Susanne BARTELS[1]; Julia QUEHL[1]; Daniel AESCHBACH[1]

[1] Institute of Aerospace Medicine, German Aerospace Center, Germany

EXTENDED ABSTRACT

Background: Disturbances of sleep represent adverse effects of nocturnal aircraft noise exposure. These disturbances can include awakening reactions, changes in the sleep depth and sleep continuity. Restorative sleep is vital for physiological and cognitive development of children. Children are less capable to estimate threats from environmental stressors and to use adequate coping strategies (1, 2). Moreover, they are in a sensitive developmental period (2). Children who are exposed to high transportation noise levels from an early age may have higher risks for cardiovascular problems in their adult life (3). Furthermore, children generally sleep longer than adults and during shoulder times of the night when (air) traffic density is high. They are therefore considered vulnerable to the negative consequences of transportation noise (4, 5). However, little is known about childhood sleep exposed to transportation noise. An investigation seemed particularly necessary due to the differences of sleep architecture between children and adults. The present study aimed at closing the research gap regarding the acute effects of nocturnal aircraft noise on sleep of primary school children.

Methods: We investigated the effect of aircraft noise on sleep in a field study in 51 children aged 8 to 10 years. All participants resided near Cologne/Bonn Airport representing an important German hub with a 24-h operating scheme. Aircraft noise was the dominant noise source at all measurement sites. Participants were screened for hearing impairments and age-adequate normal bedtimes. We excluded individuals with intrinsic sleep disorders, medical conditions, or medication use which might have interfered with the study protocol or the interpretations of the results of the study. Sleep was measured polysomnographically (via EEG, EMG, EOG, ECG, and pulse oximetry) during four consecutive nights. The first night served as adaptation to the protocol and the measurement devices. Sleep stage classification was based on the criteria of Rechtschaffen and Kales (6). In addition, subjects rated their sleep quality and current fatigue each morning using a verbal five-point scale with graphical anchors. During all nights, aircraft and ambient sounds and sound pressure levels were recorded continuously with a one class-1 sound level meter next to the children's ears. Aircraft noise exposure was quantified by the number of aircraft noise events above 30 dB(A) per night. We considered only aircraft noise events which did not overlap with sounds from other sources.

144 nights with valid data regarding acoustic as well as objective and subjective sleep measurements were available for statistical analyses. For the prediction of objective and subjective sleep quality from aircraft noise exposure, we applied mixed models with random intercept and the number of noise events as dichotomous factor (median split at 37.5 events). The following variables were analyzed: a) sleep onset latency to stage 2 (in min), b) sleep efficiency (proportion of sleep time during time in bed, in %), c) proportion of slow wave sleep (S3 and S4) per total sleep time (in %), d) proportion of REM sleep per total sleep time (in %), e) wake duration during sleep period time (in %), f) self-rated sleep quality, g) self-rated fatigue in the morning. In addition, we applied linear mixed models with random intercept to analyze the relationship between objective and subjective sleep measurements.

Results: Aircraft noise exposure affected the macrostructure of sleep. A higher number of noise events during the night was associated with a reduction of the proportion of slow wave sleep in total seep time by 2.6 % ($p = .034$) and an increase of waking during sleep period time by 1.2 % ($p = .023$).

[1] susanne.bartels@dlr.de

Sleep onset time tended to be longer by 3.3 min in nights with higher noise exposure (p = .062). Sleep efficiency was not significantly reduced in higher exposed nights (p = .112), neither was the proportion of REM sleep per total sleep time (p = .834).

Subjective sleep quality and self-rated fatigue in the morning did not differ between nights with higher and lower aircraft noise exposure (p = .694, and p = .269, respectively). Except for the proportion of wakefulness per sleep period time ($p < .001$), the above mentioned objective sleep measures were not significantly related to subjective sleep quality. On a trend level, subjective sleep quality decreased with longer sleep onset latencies (p = .055) and lower sleep efficiencies (p = .074). Self-rated fatigue increased with longer wake durations during the sleep period time (p =.036). There was no significant or trend-level relation between any of the other objective sleep parameters and subjective fatigue.

Discussion and conclusion: Our results showed an impact of aircraft noise exposure on the sleep architecture of primary school children. Significant effects were found for the proportion of slow wave sleep per total sleep time as well as wake duration during the sleep period. With exception for REM sleep, which was not affected by aircraft noise exposure, these findings are roughly in line with results from prior studies with adult participants. To evaluate the effects of aircraft noise on sleep architecture in the context of the existing body of knowledge, a comparison is sometimes drawn to the impact of intrinsic sleep and breathing disorders on sleep structure. For adults, the impact of aircraft noise on sleep is considered subtle compared to the more severe fragmentation of sleep and reduction of slow wave sleep due to, for instance, the obstructive sleep apnea syndrome (OSAS, 7). However, for primary school children, effects of OSAS on sleep architecture have been shown to be much smaller. In a very recent study (8), comparing children with OSAS to a healthy control group, the magnitude of the loss in slow wave sleep per total sleep time (3.3 %) and sleep efficiency (1.0 %) were similar to our results. These small but recurring disturbances of slow wave sleep have been postulated as a risk for metabolic, cognitive, and cardiovascular diseases (8, 9). Therefore, the consequences of chronic aircraft noise-induced loss of slow wave sleep need further investigation.

It is important to stress that the current findings and conclusions apply to a continuous nighttime noise scenario as is the case at Cologne/Bonn Airport, but they should not be generalized to all airports. Compared to other national and international airports with a night flight ban between e.g. 23:00 h and 05:00 h, the number of flights during the shoulder times of the night is moderate at Cologne/Bonn airport. It would be very important to know the consequences of a night curfew scenario. These scenarios are characterized by dense air traffic during the hours before 23:00 h, overlapping with the early part of primary school children's sleep, and by the absence of air traffic during the middle part of their sleep episode.

As found and discussed previously (10), self-assessments of sleep do not necessarily correlate with objective sleep measures in adults. Present results suggest that this holds true for children a well. With exception for wakefulness during the sleep period time, the objectively measured deterioration of sleep architecture was not mirrored by self-rated sleep quality and fatigue in the morning. Our findings underline the importance of objective measures for identifying noise-induced changes in sleep.

Keywords: aircraft noise, children, sleep, field-study

REFERENCES

1. Bruni L, Novelli R, Ferri, R Sleep disturbance in children by noise. In: Nriagu JO, editor. Encyclopedia of Environmental Health. Amsterdam, the Netherlands: Elsevier Science and Technology; 2011. p 88-94.
2. van Kamp I, Davies H. Noise and health in vulnerable groups: a review. Noise & Health, 2013;15:153–159.
3. van Kempen E, Casas M, Pershagen G, Foraster M. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cardiovascular and Metabolic Effects: A Summary. International Journal of Environmental Research and Public Health. 2018;15(379):1-59.

4. Basner M, McGuire S. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep. International Journal of Environmental Research and Public Health. 2018;15(519):1-45.
5. Stansfeld SA, Clark C. Health effects of noise exposure in children. Current Environmental Health Reports. 2015, DOI 10.1007/s40572-015-0044-1.
6. Rechtschaffen A, Kales A, Berger RJ, Dement WC, Jacobsen A & Johnson LC. A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Washington, D.C, USA: Public Health Service, U.S. Government, Printing Office.1968.
7. Basner M, Griefahn B, Berg M. Aircraft noise effects on sleep: Mechanisms, mitigation and research needs. Noise Health, 2010;12: 95-109.
8. Durdik P, Sujanska A, Suroviakova S, Evangelisti M, Banovcin P, Villa MP. Sleep architecture in children with common phenotype of obstructive sleep apnea. Journal of Clinical Sleep Medicine. 2018; 14(1): 9-14.
9. Wiater A Paditz E, Schlüter B, Scholle S, Niewerth HJ, Schäfer T, Erler T, Schachinger H. Obstruktives Schlafapnoesyndrom im Kindesalter. Deutsches Ärzteblatt. 2002;99 (49), A-3324-A3330.
10. Basner M, Brink M, Elmenhorst E-M. Critical appraisal of methods for the assessment of noise effects on sleep. Noise & Health.2013;14(61):321-329.