Update of WHO's Community Noise Guidelines: Evidence review on the effects of noise on sleep

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ABSTRACT

To evaluate the strength of the available evidence on the effects of environmental noise exposure on sleep for the update of WHO's Community Noise Guidelines a systematic review of the literature published between 2000 and 2015 was performed. A meta-analysis of surveys linking road, rail, and aircraft noise exposure to self-reports of difficulty falling asleep, awakening during the night, and sleep disturbance was conducted and exposure-response relationships were derived. A pooled analysis of polysomnographic studies on the acute effects of transportation noise on sleep was also conducted, and exposure-response functions between the maximum sound pressure level of individual noise events and the probability to wake up were derived. Due to a limited number of studies and the use of different outcome measures, a narrative review only was conducted on the effect of transportation noise on motility, cardiac and blood pressure outcome measures, and on children's sleep. The effect of wind turbine and hospital noise on sleep was also assessed. Based on the available evidence, transportation noise has an effect on objectively measured sleep physiology and on subjectively assessed sleep disturbance in adults, for other outcome measures and noise sources the evidence was conflicting or emerging.

Keywords: Sleep, Transportation Noise, Wind Turbine Noise
I-INCE Classification of Subjects Numbers: 62.5, 66.1

1. INTRODUCTION

Undisturbed sleep is importation for daytime performance, well-being, and health (1). Environmental noise has been shown to affect the restorative value of sleep by increasing the time it takes to fall asleep, decreasing total sleep time, and affecting sleep continuity (2). Up-to-date exposure-response relationships are needed to inform policy and reduce the impact in communities. The World Health Organization's Regional Office for Europe is updating the 1999 Guidelines for Community Noise (3). For this update a systematic review of studies that examined the effect of transportation, wind turbine, and hospital noise on sleep was conducted to evaluate the current state of the scientific evidence. A reanalysis of transportation noise studies that measured awakenings using polysomnography and a meta-analysis of studies that used self-reported sleep outcome measures was conducted in order to derive exposure-response relationships. A meta-analysis for studies on the effect of wind turbine noise on sleep was also completed. A narrative review only was conducted on the effect of transportation noise on motility, cardiac and blood pressure outcome measures, and on children's sleep, and also for the effect of hospital noise on sleep, due to either a limited number of studies or the use of diverse study methodologies.

2. METHODS AND RESULTS

For the literature review, databases including PSYCINFO, PubMed, Science Direct, Scopus, Web of Science, and the TNO Repository were searched. The review also included gray literature, with conference proceedings including ICBEN and INCE being searched. The search terms included the type of noise (e.g. environmental, community, traffic, road, vehicle, truck, railway, wind turbine, wind farm, airport, aircraft, hospital) and outcome measures (e.g. insomnia, sleep, cortical awakening and arousal, autonomic arousal, wake, awakening). Not all identified studies were included in the

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review. Laboratory studies or studies that played back sounds artificially were excluded due to low ecological validity. Studies on interventions (except for hospital noise) and on sleep medication use were excluded as they were included in other evidence reviews. For road, rail, and aircraft noise, studies from 2000 or later were included to provide an update to the previous guidelines. For hospital noise, all studies were included regardless of date, as this topic was not previously covered in detail. A total of 75 studies were included in the review.

2.1 Polysomnography Measured Outcomes for Road, Rail and Aircraft Noise

Four studies were identified for which the effects of road, rail, or aircraft noise on polysomnographically measured sleep was evaluated. Two of the four studies completed single event analysis and used similar methodologies. The two studies were both conducted by the German Aerospace Center (DLR); the STRAIN study was conducted to investigate the effects of aircraft noise on sleep (4) and the DEUFRAKO study was conducted to investigate the effects of rail noise on sleep (5). In both studies, physiological reactions to road noise were also measured. These two datasets were used to derive unadjusted exposure-response relationships between the probability of a sleep stage change to wake or S1 and the indoor maximum noise level ($L_{AS,max}$), separately for road, rail, and aircraft noise. A positive significant association was found between the probability of transitions to wake or S1 and the indoor noise levels for all transportation modes; a difference between transportation noise sources though was not found. However, neither the STRAIN nor DEUFRAKO study was designed to examine the effects of road noise on sleep.

2.2 Self-Reported Sleep Outcomes for Road, Rail, and Aircraft Noise

The survey questions on sleep used in studies were highly variable. Therefore it was decided to focus on the questions for the three most commonly reported sleep outcomes which were awakenings from sleep, the process of falling asleep, and sleep disturbance which was defined as interference with sleep continuity. Results for these three sleep outcome measures were not reported consistently in the literature. Therefore in order to conduct a meta-analysis authors of the papers were contacted to obtain the number of participants who reported each response alternative for each 5 dB L_{night} category. Data was obtained for 30 studies which included studies conducted in Europe and in Japan, Korea, Vietnam and Hong Kong. Response categories were combined to calculate the percent highly sleep disturbed for each of the three outcome measures. Analyses were performed separately for studies in which the questions did and did not refer to the noise source.

For questions that referred to the noise source, exposure-response functions for the percent highly sleep disturbed was calculated for questions on awakening and difficulty falling asleep, and for all three sleep outcome measures combined. A positive significant association was found between the percent highly sleep disturbed and L_{night} levels for road, rail, and aircraft noise. Pooled odds ratios for the probability of being highly sleep disturbed were also calculated for a 10 dBA increase in L_{night} level separately for studies in which the sleep questions did and did not refer to the noise source, and there was no significant effect for the latter.

2.3 Transportation Noise and Additional Sleep Outcomes

Due to a limited number of studies and different reported sleep outcomes across studies, a narrative review only was conducted on the effects of transportation noise on motility measured sleep outcome measures in adults (8 studies), cardiac and blood pressure measured outcomes at night in adults (2 studies) and studies in which sleep disturbance in children was examined (5 studies). For the studies on motility, 4 examined the relationship between the noise level of single events and probability of motility, with 4 studies comparing the relationship between average nighttime noise levels and sleep parameters that were descriptive of the entire night. Consistent evidence across studies was found however, only for those studies that conducted single-event analysis.

2.4 Wind Turbine Noise and Self-Reported Sleep Outcomes

Seven studies on the effects of wind turbine noise on sleep were identified, 6 of which used self-reported measures of sleep disturbance. Four of the 6 studies found an association between wind turbine noise and sleep disturbance but only for noise levels above 40 or 45 dBA. Odds ratios for self-reported sleep disturbance for a 10 dB increase in the noise level were calculated for 5 of the studies. The pooled odds ratio was calculated and was non-significant.

2.5 Hospital Noise and Sleep

Seventeen studies were identified on the effects of hospital noise on sleep, 5 of these studies were intervention studies. Of the non-intervention studies 3 were studies that examined the effect of noise on sleep in children. The methodologies of the studies were too diverse to conduct a meta-analysis. Four of the studies did use polysomnography to investigate the effects of noise on sleep in adults, and a weak correlation was found between arousals and events of high noise levels. However, the results of studies using other methodologies were contradictory.

3. CONCLUDING REMARKS

In this review it was found that transportation noise has an effect on objectively measured sleep physiology. However, the derived exposure-response relationships were only based on data from two studies conducted in the same region. More studies using objective measures of sleep in diverse populations are needed. It was also found that transportation noise affects self-reported sleep measures including sleep continuity, awakenings, and difficulty falling asleep. However, for self-reported sleep outcomes the strength of the evidence was dependent on the wording of the questions with a significant association found only when the question referred to the noise source. This may be partly due to the fact that the derived models were not adjusted for confounding factors. However, it also suggests that it could be attitude to the noise driving the increase in self-reported sleep disturbance with L_{night} levels. The evidence was found to be limited for nighttime blood pressure and cardiac outcomes and effects of noise on children's sleep due to the low number of studies. The strength of evidence for motility measured outcomes was conflicting as it was dependent on the type of analysis performed. For wind turbine noise, the results suggest noise may affect sleep when levels exceed 40 dBA, however evidence is still emerging and additional studies are needed using both objective noise and sleep measurements.

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