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Review of research on the effects of noise on sleep over the last 3 years

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ABSTRACT

Undisturbed sleep is important for next day performance, well-being, and health. It is known from laboratory and field studies that environmental noise can affect both sleep physiology and subjectively assessed sleep quality. To provide an overview of recent findings on the effects of noise on sleep, a literature review was conducted. Articles published since June 2014 was identified through a search of accessible databases. Studies on transportation, wind turbine, and hospital noise were included in this review. Based on the identified studies, there has been an ongoing interest in examining the acute effects of noise on sleep. Among the new actigraphy and polysomnographic field studies are the first studies on wind turbine noise which have used objective measures of sleep, as well as a study examining the potential benefit of nighttime air-traffic curfews. Also there have been new epidemiological studies which have added to the knowledge on the effects of noise on self-reported sleep disturbance. This review will include important findings over the last three years and recommendations for future research.

INTRODUCTION

To provide an overview on recent findings (2014 to 2017) on the effect of environmental noise on subjectively and objectively measured sleep, a literature search was conducted. Available scientific databases including PubMed and Web of Science were searched. Conference proceedings were also reviewed. Studies examining transportation, wind turbine, and hospital noise were included.

In the last two reviews for ICBEN Team 5 [1,2], a need for additional research on the effect of wind turbine noise on sleep, individual differences in vulnerability to noise-induced sleep disturbance, and mechanisms by which noise-induced sleep disturbance can lead to cardiovascular disease has been proposed. Also the need for new methodologies for collecting objective measures of sleep in the field has been suggested. Progress has been made during the last three years in each of these areas. Findings of the identified studies are summarized below.

AIRCRAFT NOISE

Schmidt et al. [3] provided evidence on a potential mechanism that may contribute to the observed finding in epidemiologic studies of an increased risk of cardiovascular disease with noise exposure. They examined the effect of simulated nocturnal aircraft noise on 60 individuals with coronary artery disease or at high risk of developing coronary artery disease. Participants were exposed to 60 simulated aircraft noise events at night in their own bedroom and there was also a control night without aircraft noise. The average noise level (L_{Aeq}) for nights with aircraft noise was 46.9 $\pm$ 2.0 dB and for the control night was 39.2 $\pm$ 3.1 dB. It was found that flow-mediated dilation of the brachial artery was significantly reduced after nights with aircraft noise exposure. Decreased flow-mediated dilation has been found to be predictive of future cardiovascular events. Average systolic blood pressure during the sleep period was also found to be significantly increased by 4.1 mmHg for nights with aircraft noise.

There have been two new community surveys conducted. Kwak et al. [4] conducted a survey near Gimpo International Airport in Korea. Participants were sampled from a high (80-90 WECPNL) and low (75-80 WECPNL) noise region, which were defined based on the Weighted Equivalent Continuous Perceived Noise Level (WECPNL). They also had a control region without aircraft noise exposure, which had similar socio-demographic characteristics. The Insomnia Severity Index, which contains 7 questions related to daytime fatigue, sleep maintenance, and difficulty falling asleep, was used. After adjusting for relevant confounding factors, the risk of insomnia was found to be 3.41 times higher in the low noise exposure group (95% CI 2.61-4.46) and 3.26 times higher in the high exposure group (95% CI 2.50-4.25) then the control group. However, the high exposure group was not found to have a higher risk then the low noise exposure group. Nguyen et al. [5] conducted face-to-face interviews in communities near Hanoi Noi Bai International airport in Vietnam. One survey was conducted before the opening of a new runway, and 2 surveys after the opening. Logistic regressions for the percent reporting their sleep was very disturbed by aircraft noise, with outdoor L_{night} levels as the only explanatory variable, were calculated. The results from the three logistic regressions were found to be similar. Only a small additional affect after the opening of the new runway was found, which consisted of a slight increase in reported sleep disturbance for noise levels above 50 dB.

Two field studies obtained objective measures of sleep. A three year sleep study was conducted as part of the NORAH study around Frankfurt airport [6]. Measurements in 2011 were made before a restriction on nighttime flight operations and measurements in 2012 and 2013 were made after flights were banned between 23:00 and 5:00. Polysomnography was used in the first two years of the study with concurrent indoor noise measurements within the bedroom. Each participant completed 3 nights of measurements. The probability of awakening did not differ significantly between the first two years (before and after the ban), nor did sleep onset, or time spent awake after sleep onset.

A pilot field study was conducted by Basner et al. [7] in the U.S. near Philadelphia airport; half of the participants were recruited from a control region and half from a region near the airport. The participants completed unattended physiological measurements of heart rate and body movement and indoor noise measurements in the bedroom, for 3 nights. It was found that participants could complete the protocol on their own with minimal data-loss. The ECG and actigraphy approach used reduces the methodological cost for obtaining objective measures of sleep in communities by eliminating the need for staff in the field each day.

ROAD NOISE

Brown et al. [8] conducted a survey in Hong Kong, in which 10,077 respondents were included. An exposure-response curve was derived which related the percent highly sleep disturbed due to road noise to the outdoor L_{night} levels. The obtained curve was found to be similar to both the Miedema and Vos [9] and Hong et al. [10] curves. The results indicate a similarity in reported sleep disturbance due to road traffic noise between European and Asian countries.

Evandt et al. [11] used data from the Health and Environment Study conducted in Oslo, Norway which consisted of 13,019 responses, to examine the association of modeled L_{night} road traffic noise levels at the most exposed façade with insomnia and self-reported sleep medication use. No association was found between L_{night} and sleep medication use. A positive significant association though was found for a 5 dB increase in L_{night} for participants reporting difficulty falling asleep (OR 1.05, 95% CI 1.01-1.09), awakenings during the night (OR 1.04, 95% CI 1.00-1.08), and waking up too early (OR 1.06, 95% 1.02-1.11) three or more times a night.

Pirrera et al. [12] evaluated actigraphy measured sleep in two groups of participants; 23 lived in an area with high levels of road traffic (mean outdoor L_{Aeq} during time in bed = 61.5 dBA) and 22 lived in a quieter area (mean outdoor L_{Aeq} during time in bed = 51.2 dBA). Noise levels were recorded inside and outside the bedroom and participants wore actigraphs and completed sleep logs for seven nights. There was a 10 dB difference in the mean outdoor L_{Aeq} (calculated for time in bed period) between the high and low noise group, however there was not a significant difference in the indoor L_{Aeq} levels. Individuals in the high noise group spent less time in bed (high noise group: 433 minutes, quiet group: 451 minutes), however there was no statistically significant differences between the two groups for sleep onset latency, wake after sleep onset, or sleep efficiency. This study emphasizes the importance of obtaining indoor and outdoor noise levels.

TRAIN NOISE AND VIBRATION

Smith et al. [13] examined the effect of combined exposure to train noise and vibration on polysomnographic measured sleep parameters in a laboratory study. There were four noise exposure nights, which varied in number of events (20 or 36 events), and vibration level (moderate and high). An increased probability of combined awakenings and arousals was found for the high vibration nights compared to the moderate vibration nights. However, the event related awakenings and arousals were found to replace those that would have occurred spontaneously and did not increase the total number of awakenings or arousals.

MULTIPLE TRANSPORTATION SOURCES

Bodin et al. [14] examined whether there is a benefit of access to a quiet side. They modeled railway and road traffic noise $L_{Aeq,\ 24hr}$ separately and then combined the estimates. They found that the odds ratio for self-reported poor sleep quality for a 5 dB increase in the outdoor $L_{Aeq,\ 24hr}$ was 1.26 (95% CI 1.16-1.38). When the odds ratio was adjusted for the bedroom facing green space it equaled 0.78 (95% CI 0.64-1.00), suggesting a potential benefit of bedroom position.

Perron et al. [15] examined self-reported sleep disturbance in 4336 individuals in Montreal exposed to single or multiple sources of noise. Noise exposure was categorized based on a Noise Exposure Forecast Contour (NEF) for aircraft, distance to roads and highways, and distance to rail lines and rail yards. Those exposed to road and rail noise were found to have more sleep disturbance than those exposed to road noise only. In addition, for aircraft and road noise, they found a significant association between noise-sensitivity and reported sleep disturbance.

Inter-individual differences in awakening probability to road, rail, and aircraft noise in a laboratory study were examined by McGuire et al. [16]. Data from the AIRORA study was used which consisted of 69 participants who were exposed to either one or multiple noise sources for 8 nights. It was found that 40.5% of the variance in probability of awakening was due to inter-individual differences which cannot be explained by age, gender, study night or number of noise events.

WIND TURBINE NOISE

There have been several new studies conducted on the effects of wind turbine noise on sleep which includes two that have used objective measurements. Jalali et al. [17] conducted a study in Ontario, Canada which included 16 participants who completed two consecutive nights of sleep measurements before and after the start of operation of new wind turbines. Polysomnography was used to measure sleep, and noise recordings were made inside participant's bedrooms. No significant difference in objective sleep parameters was found between the two measurement periods. A decrease in reported sleep quality and an increase in daytime sleepiness though were found after the wind turbines were operational. Michaud et al. [18] also obtained objective and subjective measures of sleep for individuals exposed to wind turbine noise in Canada. A total of 1238 households completed subjective assessments of sleep which included the Pittsburgh Sleep Quality Index (PSQI). No association was found between the mean PSQI scores and modeled outdoor noise levels. Participants were also asked to report the magnitude of their sleep disturbance during the last year, no association was found with noise level. Actigraphy was used to objectively measure sleep parameters for 7 nights in a subsample of 654 participants. No significant association was found between wind turbine noise levels and any actigraphy measured outcomes.

There were 4 additional studies conducted that obtained subjective evaluations of sleep only. Magari et al. [19] conducted a survey in Western New York State (Wethersfield, NY). Indoor and outdoor measurements (L_{Aeq}) were obtained for 10 minutes. A total of 62 individuals from 56 different homes completed in-person interviews, 26% reported sleep disturbance. Self-reported sleep disturbance was not directly compared to the measured noise levels. However, the authors did report that there was no significant correlation between concerns for negative health effects and indoor or outdoor L_{Aeq}. Song et al. [20] conducted a survey in China, 251 responses were obtained. Outdoor 15 minute noise measurements were completed for 65 houses, with measured noise levels ranging from 44.1-56.7 dBA. It was found that almost all respondents (93.4%) reported difficulty sleeping. The authors stated that the wind farm had a higher capacity than previous studies. Also a higher percentage of respondents had a negative view of wind turbines (58.6%) and reported being highly noise sensitive (69.6%) than in previous studies conducted in Sweden and the Netherlands [21-23].

Pawlaczyk-Luszcynsa et al. [24] conducted a survey in Poland. The proportion of individuals reporting that they suffer from sleep disturbance at least a few times per week was significantly higher in individuals exposed to wind turbine noise levels of 40-45 dBA (L_{den}) compared to those exposed to levels of 35-40 dBA (26% vs 10.2%, $p<0.05$). Kuwano et al. [25] examined self-reported insomnia in a study conducted in Japan. This study included both a wind turbine noise exposed group and a control group. Insomnia was defined as having difficulty falling asleep, maintaining sleep, prematurely awakening, or having light sleep at least 3 times a week for any reason. The insomnia prevalence rate in the study was low, with 3.1% of participants exposed to L_{night} 41-45 dB and 2.7% of participants exposed to an L_{night} of greater than 45 dB reporting insomnia. Kuwano et al. also stratified their data by noise sensitivity, and a significant association between insomnia and L_{night} was only found in the noise sensitive population, though this analysis was limited due to the very low insomnia prevalence rate in the study.

HOSPITAL NOISE

Park et al. [26] conducted a study to examine the effect of noise on sleep in an internal medicine hospital ward. Noise levels were measured in 29 hospital rooms, and 109 patients completed the Pittsburgh Sleep Quality Index. PSQI scores were found to increase with mean daytime and nighttime levels (β=0.2; 95% CI=0.09-0.53 for daytime; β=0.12; 95% CI=0.07-0.36 for nighttime). The estimates were controlled for age, gender, and severity of disease, medication, and room type.

NOISE METRICS

Wunderli et al. [27] proposed a new noise metric, the intermittency ratio (IR). An IR of >50% indicates that the noise is defined by separate or distinct events; while a more constant noise e.g. highway noise has a low intermittency ratio. A laboratory study was conducted in which 21 healthy adults were exposed to 4 different noise scenarios (3 consisting of road traffic noise and 1 of train noise) which had the same L_{Aeq} level but different intermittency ratios. No significant difference in sleep stage durations was found across noise conditions; however an increase in arousals during NREM sleep was found for nights with noise of a high intermittency ratio [28].

RESEARCH OUTLOOK

There were several new studies conducted in the past three years, however all of the identified studies were conducted in adult populations. Only a limited number of previous studies have examined the effects of noise on children's sleep [29-32], which have primarily used self-reports of sleep disturbance. Studies using subjective and objective assessments of sleep in children are needed, as well as studies examining next day effects on children's behavior and performance. The German Aerospace Center is currently conducting a polysomnographic study in children 8-10 years old exposed to aircraft noise which may provide new information in this area.

Out of the 6 studies on wind turbine noise that have been published since 2014, 5 have found an association between wind turbine noise and self-reported sleep disturbance. However, no significant associations between wind turbine noise and objective sleep measurements have been found. Outdoor average (L_{Aeq}) predicted and measured wind turbine noise levels in field studies are generally below 45 dBA. However, sound characteristics in addition to the average noise level may impact whether someone's sleep is affected. A recent laboratory study (WiTNES) [33] has been conducted which may provide information on the sound characteristics of wind turbines that may lead to objectively measured sleep disturbance, such as presence of beats and strength of amplitude modulation.

The study by Schmidt et al. was the only one reviewed that examined a potential mechanism in which sleep disturbance due to nighttime noise exposure may lead to long term health effects. Recent advances in knowledge on metabolic, vascular and neurophysiological impacts of inadequate sleep [34-36] could pave the way for future studies on the long-term effects of night-time noise including outcomes such as obesity, cardiovascular disease as well as neurodegenerative disorders. Thus both longitudinal studies as well as studies examining potential pathways between noise-induced sleep fragmentation and impacts on health are still needed.

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