

Noise Induced Sleep Disturbance in Adult Population: Cross Sectional Study in Skopje Urban Centre

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Abstract

Key words:

Noise; environmental exposure; sleep disorders; threshold limit values; odds ratio; public health.

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Aim. To evaluate sleep disturbance caused by environmental noise in residents of Skopje urban centre and to quantify the probability for sleep disturbance related to night-time noise exposure.

Methods. Cross sectional study with noise measurements for determination of noise exposure indicator L_{night} . A randomised sample was selected from adult population and directly interviewed with questionnaire for assessment of sleep disturbance.

Results. 510 questionnaires were collected and the response rate was 72%, 8% of the population sample reported a high level of sleep disturbance and 18% reported a moderate level of sleep disturbance. The most frequent sources of noise were neighbourhood and road traffic. The most disturbed age group were individuals 51-65 years old, who were significantly more disturbed ($p=0.010$) than the age group of 41-50 years old. Differences in sleep disturbance were significant only for the group exposed to $L_{\text{night}} \geq 56$ dBA (Wald = 4.31; $p = 0.04$). Exposure to L_{night} above 56 dBA had OR = 2.2 (95% CI 1.1 - 4.7) or double significant increase probability for sleep disturbance, compared with control group of subjects exposed to $L_{\text{night}} \leq 45$ dBA.

Conclusion. Night time noise exposure above the established limit values significantly increased the risk for sleep disturbance. These findings induce necessity for reducing noise exposure, especially during night-time and for taking preventive measures.

Introduction

Environmental noise is one of the major environmental hazards in developed and developing countries, originating from a wide variety of sources, including traffic (air, road, or rail), industrial facilities, or social activities. About 40% of the population in the European Union are exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dBA at daytime, whereas 20% are exposed to levels above 65 dBA, more than 30% of Europeans are exposed to night time noise exceeding 55 dBA, which may cause sleep disturbance (1).

The adverse health effects of environmental

noise pose a serious public health problem and they are hearing impairment, interference with speech communication, annoyance, sleep disturbance, cardiovascular effects, cognitive impairment in children. The pathophysiological basis for a noise-sleep relation may be the stimulation of hypothalamus-pituitary-adrenal axis, adrenal medulla, and sympathetic nervous system with a subsequent release of "stress hormones" (adrenaline, noradrenaline, and cortisone) (2,3).

Among the extra auditory effects, sleep disturbance is a common effect described by most of the noise exposed populations and their complaints are

often very impressive. The survey of the literature shows large differences between results obtained in numerous laboratory studies and those issued from epidemiological or experimental studies made in real situations. It seems obvious that certain degree of habituation occurs in the field for the provoked awakenings, while some objective adaptation is building up progressively. On the other hand autonomic response do not habituate over extended period of chronic exposure (4).

Adverse health effects are expected from chronic noise induced sleep disturbance, as it impairs the functions of sleep such as brain restoration and provision of a period of respite for the cardiovascular system. In addition to the physiologic aspects of a noise-induced reduction of sleep quality, night-time noise exposure of sufficient intensity is also related to subjectively experienced sleep quality. Reduced sleep quality also interferes with daytime functioning and can have adverse effects on mood next day and possibly on vigilance and cognitive performance (5). Sleep disturbance can be quantified by subjective and objective methods. The most commonly applied subjective methods are self-reporting using sleep logs or diaries and, to a lesser extent, behavioural observations. The most commonly used objective methods are electroencephalograph (EEG) recordings and actimetry (4, 5).

The capital of Macedonia, Skopje, has become a typical urban centre, and a good example for an urban noise polluted area, with already established mixed residential administrative market areas, where we expect increased level of noise exposure (6, 7). Therefore, we conducted a cross sectional study to evaluate sleep disturbance caused by environmental noise in residents of Skopje urban centre and to quantify the probability for sleep disturbance related to night-time noise exposure.

Material and Methods

Sample

The sample for this study was randomly selected from the population living in Skopje, on different location of the city: in the center of the city, on nearby streets with heavy traffic (Madzhari), in mixed residential-administrative – market areas (Aerodrom, Chair), and in suburban areas where we expected low noise level (Gjorche Petrov). Randomization of the sample was performed by using addresses in studied areas, we selected buildings, than we se-

lected every third flat in the building, and finally one member of family who agreed to participate. Inclusion criteria for subjects were age (between 18-65 years) and at least one year of residence at the current living address. We selected 700 subjects for interview with questionnaire for assessment of noise induced health effects.

Questionnaire

The questionnaire was prepared in order to assess noise induced adverse health effects in exposed population, according to ISO/TS 15666:2003 and according to the gained experience from a previous research (8). This questionnaire included the question: "Do you think that your sleep was disturbed due to night-time noise or noise events during the night in the last twelve months and more?". Using a five-item verbal scale and a eleven-point numerical scale, the interviewed subjects responded to the question. Five-item verbal scale contained the verbs: "not at all, very little, moderate, high and very high". Answers "high and very high" were evaluated as high level of sleep disturbance, answers "not and very little" were evaluated as not disturbed during sleeping. On the numerical scale 0 was equivalent to "not at all disturbed" and 10 was equivalent to "extremely disturbed". Values from 0-4 meant that subjects were not disturbed, 5-7 moderately disturbed and 8-10 highly disturbed (8, 9).

Noise measurements

We determined the measurement points for environmental noise in the central part of the Skopje urban centre, residential-administrative-market area burdened with traffic and various activities and in the suburban residential area, nearby the city. Measurements points were allocated in different parts of the city, aiming to cover areas with different noise levels and to determine the noise level where subjects live. Measurements were performed with a sound analyzer Bruel & Kjaer, type 2260 Investigator, during one week in the spring and one week in the autumn in 2006. We performed two measurements of noise, each one for 15 minutes during night (from 23h-07h) for determination of indicator L_{night} (average equivalent energy noise level during night). We decided to use L_{night} as a noise exposure indicator during the night according to both European legislation and national legislation, as well as WHO recommendations (5). The subjects were grouped according to 5dBA categories of the L_{night} , starting with 45 dBA, as a previously established limit value for prevention of sleep disturbance (3).

Statistical analysis

Statistical program Statistica 7.1/2005, SPSS 13.0 was used to determine average value, standard deviation, $\pm 95\%$ CI (confidence intervals) for numerical data series, percentage distribution for categorical data series, difference between two proportions (p) and Mann-Whitney U test for testing the association between analyzed parameters. The multiple logistic regression technique was applied to calculate estimates of the OR (odds ratio) and the confidence intervals for sleep disturbance, compared with control group (10).

Results

The total number of respondents was 510, and the response rate was 72%, 243 (47.6%) male and 267 (52.4%) female. The average age of subjects was 37.3 ± 14.4 years ($\pm 95\%$ CI 36.1 – 38.6).

The average value of L_{night} (night-time noise level) was $56 \text{ dBA} \pm 6.5 \text{ dBA}$, ($\pm 95\%$ CI 55 - 56). We used L_{night} as an exposure indicator of night noise and we classified the subjects according to L_{night} value and residential address in four study groups. The results showed that only 18 (3.5%) of the subjects were exposed to $L_{\text{night}} \leq 45 \text{ dBA}$, 115 (22.5%) were exposed to L_{night} ranging from 46 to 50 dBA, 146 (28.6%) were exposed to L_{night} ranging from 51-55 dBA, and most of the subjects - 231 (45.4%) were exposed to $L_{\text{night}} \geq 56 \text{ dBA}$.

Analysis of the sleep disturbance level in the entire sample according to the scale 0-10, has shown that 8.2% of subjects have reported a high level of sleep disturbance, 17.8% have reported a moderate level of sleep disturbance and 74% had no sleep disturbance induced by noise. In fact, 26% of subjects reported noise-induced sleep disturbance, this finding is important for evaluation of noise-induced sleep disturbance and to compare with other countries (Fig. 1).

Analysis of the sleep disturbance level according to the five-verbal scale and according to the noise sources has shown that the most frequent noise sources for sleep disturbance were neighborhood and road traffic noise, both in about 17% of subjects; noise from construction activities caused sleep disturbance in 16% of subjects; noise from leisure activities in 14.5%; noise from restaurants, cafeterias etc in 12%. Railway and aircraft traffic noise caused no sleep disturbance in subjects.

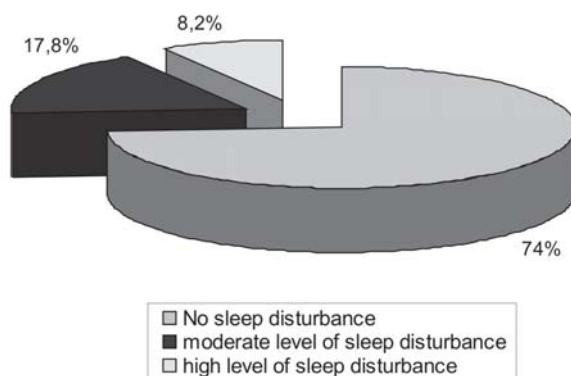


Figure 1: Percentage of subjects with sleep disturbance in the entire sample.

Female subjects reported a higher level of sleep disturbance, 9.7% of women had a high level of sleep disturbance and 19% had a moderate level of sleep disturbance. 6.5% of male subjects reported a high level of sleep disturbance and 15% had a moderate level of sleep disturbance. Differences in self-reported sleep disturbances between male and female subjects were not significant ($p > 0.05$) (Table 1). Noise exposure to different L_{night} levels was not considered when we were looking for differences between genders.

Table 1: The level of sleep disturbance according to the gender of subjects.

| Gender of subjects | No sleep disturbance | | Moderate level of sleep disturbance | | High level of sleep disturbance | |
|-----------------------------|----------------------|------|-------------------------------------|------|---------------------------------|-----|
| | Number | % | Number | % | Number | % |
| Male | 189 | 77.8 | 38 | 15.6 | 16 | 6.6 |
| Female | 189 | 70.8 | 52 | 19.5 | 26 | 9.7 |
| Significance of differences | $p=0.12$ | | $p=0.63$ | | $p=0.73$ | |

Differences in sleep disturbance in the exposed population, adjusted to confounded variables like employment, educational level, residential period at the current address, time spent at home during working days and at weekend were not significant. We found significant differences in sleep disturbance when we included acoustic isolation of the dwelling as confounded variable. Only acoustical isolation of the dwelling showed significant differences in the level of sleep disturbance, OR = 0.5 (95% CI 0.3-0.8), $p=0.009$. This finding has presented a clear relation between isolation of the dwelling and sleep disturbance the exposed population, or we can say isolation significantly decreases the probability for sleep disturbance in the exposed population.

Concerning the differences in the level of sleep disturbance according to subject's age, we found out

that 32% of subjects aged 51-65 years reported sleep disturbance. The second affected group were 18-30 years old subjects, 9.9% of them reported a high level of sleep disturbance and 19.6% had a moderate level of sleep disturbance. Subjects at the age of 41-50 years were more resistant to the night-time noise exposure; only 7% of them reported sleep disturbance. In fact we found significant differences in sleep disturbances, between subjects at the age of 41-50 years and subjects at the age of 51-65 years for, $Z = -2.5$ and $p = 0.01$. Differences in sleep disturbance between other age groups were not significant and noise exposure to different L_{night} levels was not considered.

Finally, we compared the differences in sleep disturbance level related to the level of night-time noise exposure. We used a multivariate logistic regression analysis for determination of probability to develop sleep disturbance in the exposed population to night time noise above 46 dBA, so reference group comprised subjects exposed to $L_{\text{night}} \leq 45$ dBA. Noise exposure to $L_{\text{night}} \geq 56$ dBA had greater influence (Wald = 4.31) and significant influence ($p = 0.04$), noise exposure to 46-50 dBA had less influence (Wald = 1.75) and non-significant influence ($p = 0.19$). Group exposed to 51-55 dBA was not included because testing has shown there are no differences with reference group. Values of odds ratio (OR) have shown that night-time noise exposure above 56 dBA had significantly increased probability for sleep disturbance. Subjects exposed to night time noise above 56 dBA had 2.2 (OR = 2.2 95% CI 1.1-4.7) times significant probability to develop sleep disturbance compared to subjects exposed to $L_{\text{night}} \leq 45$ dBA (Table 2).

Table 2: Logistic regression analysis for sleep disturbance and night time noise (compared with reference group exposed to $L_{\text{night}} \leq 45$ dBA).

| Noise exposure dBA | Wald | p | OR | 95.0% CI for OR |
|--------------------|-------|--------|-------------|------------------|
| 46-50 | 1.75 | 0.19 | 0.41 | 0.11-1.53 |
| ?56 | 4.31 | 0.04 | 2.21 | 1.05-4.67 |
| Constant | 70.21 | <0.001 | 0.07 | |

Discussion

Noise is produced by a large variety of sources in various environments and as most of the people are complaining, they are exposed to different noise sources, defined as multiexposure. Different indicators have been used to describe noise exposure and there is no general agreement on which should be

preferred among integrated energy indicators L_{Aeq} , L_{day} , L_{night} , L_{Amax} , SEL (sound exposure level) (1). Some authors think that is very difficult to correlate energy integrated indicators with actual sleep disturbance and peak sound levels are better predictors of sleep disturbance (1, 4, 11). Another study showed that psychosocial well-being of subjects exposed to high levels of road traffic noise was not related to daytime noise exposure but to night-time equivalent sound level in the bedroom and to subjectively experienced sleep quality (12). According to European legislation and WHO Guidelines for Community Noise, we decided to use L_{night} as a night time exposure indicator and sleep disturbance as noise effect indicator (1, 2, 5, 13, 14). Also we used 45 dBA as a limit value for prevention of sleep disturbance, which was already established in the national legislation for noise management, based on WHO recommendations (1, 5). Our efforts were to make a representative sample, with adjusted participation of subjects exposed to different indicators levels, and we finally developed a sample of subjects who were exposed to elevated level of noise indicators; 45% of subjects exposed to $L_{\text{night}} \geq 56$ dBA and 3,5% of subjects exposed to $L_{\text{night}} \leq 45$ dBA. This is an additional evidence that residents in Skopje are exposed to elevated noise levels in their residential environments.

This study has shown that 26% of the entire sample had sleep disturbance, according to eleven-point numerical scale and dominant sources were neighborhood noise and road traffic noise, according to five-item verbal scale. The findings have shown similarity with findings of LARES study. LARES study, organized by WHO, conducted in 8 European countries has shown that 23% of the whole sample had sleep disturbance and a dominant noise source was traffic noise (including road traffic, railway noise and aircraft noise), as well as neighborhood noise. Our questionnaire was prepared by complying it with the model of LARES study questionnaire. Thus, similar findings might be a result of the similar questionnaire used or of the similar situation in our country and European region (15). Surveys conducted in 1998 and 2003 in the Netherlands, shown that 18% of subjects in 1998 and 25% in 2003 were with sleep disturbance. The main sources for noise-induced sleep disturbance were road traffic noise, neighbourhood noise and aircraft noise (9). This is another confirmation that investigation or field study should be performed for assessment of sleep disturbance in exposed population for several reasons. Case by case research is the most appropriate way to identify

the noise sources, to take into account specific environmental conditions and non-acoustical factors in the community response to noise.

The physiological sensitivity to noise depends also on the age of subjects and we found that the most sensitive subjects were at the age of 51-65 years, and there was significant difference in comparison with subjects at the age of 41-50, who were less sensitive group. It is very well-known that elderly people complain much more than younger adults about environmental noise and spontaneous awakenings occurring during the night sleep are much more numerous. So, it is difficult to conclude if elderly people are more sensitive to noise or if they hear noise because they are often awake during the night. The natural fragmentation of their night sleep tends also to delay return to the sleeping state and this is considered to be a significant part of their subjective complaints (5).

Differences in sensitivity to noise between both sexes were already confirmed for some age groups, young men complain more about noise-induced sleep disturbance than young females. The differences seems to reverse for population over 30 years of age and then females, often mothers, appear to be more sensitive to noise than males (Lukas, 1972, Muzet et al., 1973) (4, 5). However, in our study we didn't find overall significant differences in sleep disturbance between males and females.

A very important finding of this study is quantification of the probability for sleep disturbance in population exposed to elevated night time noise. According to OR value, we found that night-time noise above 56 dBA for two times (OR = 2.2; 95% CI 1.1-4.7, $p=0.04$) significantly increases probability for sleep disturbance, compared with control subjects exposed to $L_{\text{night}} \leq 45$ dBA. A certain degree of habituation to noise does exist, if the noise load is not in excess, subjective habituation can occur in a few days or weeks. But this habituation is not complete and the measured modifications of the cardiovascular functions still remain unchanged over long periods of exposure time (16). It is not excluded that this long-term effect could perhaps lead to permanent cardiovascular system impairment (17, 18).

Jakovlevic et al., 2006 in their study have found that sleep disturbances were significantly more pronounced in urban population of Belgrade exposed to traffic noise above 65 dBA than in respondents living in a quiet area. Also they found that personality traits of neuroticism, extroversion, and

subjective noise sensitivity and noise annoyance had a significant modifying effect on this relationship. In their study, they demonstrated that residence in a noisy area was a significant predictor for difficulties in falling asleep (OR = 2.7 95% CI 1.3-5.8), difficulties with falling back to sleep (OR = 1.9), waking up at night (OR = 2.6), sleeping by closed windows (OR = 13.5), having a poor sleep quality (OR = 2.9), and feeling tired after sleep (OR = 2.5) (19).

A working group for night-time noise guidelines (WHO, Lisbon, 2005) has concluded that L_{night} should be used as an indicator for night-time noise exposure, evidence suggested that outdoor $L_{\text{night}} > 42$ dBA induced sleep disturbances and $L_{\text{night}} = 42$ dBA should be considered as NOAEL (no observed adverse effect level) for sleep disturbances. The same conclusions clearly address that NOAEL for myocardial infarction is L_{day} 60-65 dBA outdoors and L_{night} outdoors 50-55 dBA for road traffic (3). Chronic exposure to environmental noise increases the risk for hypertension (5).

Classical biological risk factors have been shown to be elevated in subjects that were exposed to high levels of traffic noise. Persistent noise stress increases the risk of cardiovascular disorders, including high blood pressure and ischaemic heart disease. Night time noise exposure above the established limit values significantly increased the risk for sleep disturbance, these finding induce necessity for reducing the noise exposure, especially during night-time and for taking preventive measures for specific groups exposed to elevated noise levels.

This is the first national study for assessment of noise-induced sleep disturbances in the adult population in Macedonia. It has shown the extent of the environmental problem and its effects on the exposed population; it emphasizes the need of protection of the possible vulnerable groups, especially during night-time; it has also given directions for further investigations related to vulnerable groups. Furthermore, it would be of benefit if directions of this study are implemented in the new public health policy and other related policies (transport, space planning, urbanisation) and strict application of noise management regulations.

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