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Psychosocial Effects of Community Noise: Cross Sectional Study of School Children in Urban Center of Skopje, Macedonia

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Aim. To assess noise exposure in school children in urban center in different residential areas and to examine psychosocial effects of chronic noise exposure in school children, taking into account their socioeconomic status.

Methods. We measured community noise on specific measurement points in residential-administrative-market area and suburban residential area. We determinated the average energy-equivalent sound level for 8 hours (LAeq, 8 h) or 16 hours (LAeq, 16 h) and compared measured noise levels with World Health Organization (WHO) guidelines. Psychological effects were examined in two groups of children: children exposed to noise level LAeq, 8 h >55 dBA ($n=266$) and children exposed to noise level LAeq, 8 h <55 dBA ($n=263$). The examinees were schoolchildren of 10-11 years of age. We used a self-reported questionnaire for each child – Anxiety test (General Anxiety Scale) and Attention Deficit Disorder Questionnaire intended for teachers to rate children's behavior. We used Mann Whitney U test and multiple regression for identifying the significance of differences between the two study groups.

Results. School children who lived and studied in the residential-administrative-market area were exposed to noise levels above WHO guidelines (55 dBA), and school children who lived and studied in the suburban residential area were exposed to noise levels below WHO guidelines. Children exposed to LAeq, 8 h >55 dBA had significantly decreased attention ($Z=-2.16$; $p=0.031$), decreased social adaptability ($Z=-2.16$; $p=0.029$), and increased opposing behavior in their relations to other people ($Z=-3$; $p=0.001$). We did not find any correlation between socioeconomic characteristics and development of psychosocial effects.

Conclusion. School children exposed to elevated noise level had significantly decreased attention, and social adaptability, and increased opposing behavior in comparison with school children who were not exposed to elevated noise levels. Chronic noise exposure is associated with psychosocial effects in school children and should be taken as an important factor in assessing the psychological welfare of the children.

Key words: *child development; noise, transportation; psychological tests; social class*

Community noise (also known as environmental noise or residential noise) is defined as noise emitted from all sources except that of the workplace. The main sources of community noise are traffic, industries, construction, public work, and neighborhood. The effect of the combination of noise events is related to the combined sound energy of those events, the equal energy principle. The sum of the total energy over a certain period of time gives a level equivalent to the average sound energy over that period. Thus, average energy Equivalent Level of the A-weighted sound over a period T (LAeq, T) has been introduced in determining the noise level (1,2). The A-weighting filter is most commonly used in noise measurements because it weighs lower sound frequencies as less important than mid and higher-frequencies as more important. LAeq, T should be used to measure continuing sounds, such as road traffic noise (1,2).

Adverse health effects of community noise in the exposed human population are expressed as non-auditory effects of noise, such as annoyance, sleep disturbance, speech intelligibility disorders, cardiovascular effects, as well as cognitive-behavioral disorders in schoolchildren. Many experimental and epidemiological studies have identified the stressful influence of noise and the consecutive elevated secretion of stress hormones (3). Interactive or transactional model for stress, which considers the source of stress, the perception of the situation, and the stress-response is the most useful approach for providing guidelines for the study of stress (4). However, there is little empirical evidence to support the key assumption of the theory that children exposed to elevated levels of community noise are, in fact, under stress (3).

Evans et al (5,6) concluded in their study that aircraft noise levels far below those necessary to pro-

duce hearing damage cause stress among children of 9-11 years of age. Haines et al (7-9) found that aircraft noise had a main direct effect on sustained attention in children aged 8-11years, and that sustained attention possibly acts as a mediator between noise and cognitive impairment.

Lercher et al (10) investigated the health effects of everyday noise exposure, which exceeds the national standards for noise. Almost all authors introduce socioeconomic characteristics of subjects as the confounding factors in stress response (6-9).

Republic of Macedonia has deficiency of national environmental health standards for noise pollution. Therefore we had to use World Health Organization (WHO) guidelines for the assessment of human exposure and of health risk. We studied psychosocial characteristics of children exposed to environmental noise in an urban, developing center in a country undergoing rapid socioeconomic changes. The capital of Macedonia, Skopje, has become a typical urban center, and a good example for an urban noise-polluted area. Over the last years, traffic intensity has increased together with the inappropriate urban and spatial planning of the residential area.

We focused on the relation between typical everyday noise levels and psychosocial effects in school children. Psychological health in children is usually measured in one of the three ways: psychiatric evaluation, self-reported questionnaire, or teachers' or parents' rating of mental health. First we assessed noise exposure of schoolchildren in different residential areas of the urban center and then we examined psychosocial effects of chronic noise exposure, taking into account the socioeconomic status of children.

Material and Methods

We performed a cross-sectional study of community noise exposure and its effects on mental health of school children, performed during 2002, in Skopje, Macedonia.

Community Noise Exposure Assessment

We measured the community noise in the central part of Skopje, Republic of Macedonia, which is the residential-administrative-market area with school and preschool facilities, as well as in our entirely suburban residential area, nearby the urban center of Skopje. Measurement points were allocated to schoolyards, crossroads, and nearby schools, which are situated in the residential area of the examined children. Measurement of community noise was performed with the sound analyzer Bruel & Kjaer, type 2260 Investigator (Bruel & Kjaer, Narum, Denmark), during four weeks in spring and four weeks in autumn of 2002. We measured noise three times in 15 minute intervals, during 8 hours to determine the average energy equivalent sound level for 8 hours in the schoolyard (LAeq, 8 h). The average energy equivalent sound level for 16 hours in a residential area (LAeq, 16 h) was measured 4 times in 15 minutes intervals during 16 hours on the crossroads in the residential area. We used the WHO guideline values for evaluating the measured noise levels (2). We used outdoor noise for assessing the noise exposure of children for several reasons. LAeq, T is a worldwide-accepted parameter for noise measurements and the monitoring of noise. The WHO has already recommended guidelines for this parameter in specific environments (school and preschool objects, hospitals, and residential objects) and many authors who are working on noise exposure assessment use LAeq, T for outdoor noise.

Sample

The sample included 266 school children, 130 boys and 136 girls, attending the fourth grade in four different primary schools located in the central part of the urban center of Skopje, and 263 school children, 134 boys and 129 girls, from three primary schools located in the suburban residential area, nearby Skopje. They were aged 10-11, and were chosen because they were in the third phase of cognitive development, which is a concrete operational period (11). In this phase children have the ability for multiple relations, to accept more than one stimulus at the same moment, but they have limited strategies for coping with environmental stress-factors.

Psychological Tests

We used the General Anxiety Scale-Sarason to test anxiety (12). Teachers evaluated childrens' behavior by administering an Attention Deficit Disorder Questionnaire (13). Teachers made ratings from 1-5 answering the questions about the childrens' attention, hyperactivity, social adaptability, and opposite behavior.

Socioeconomic Status

Socioeconomic status was estimated by using self-reported data from parents on their employment, education and housing (ratings from 0-3). The parents were asked to fill the questionnaire during a parents-teacher meeting in the school.

Statistical Procedures

We used STATISTICA for Windows 1995 (Version 5.1, StatSoft, Inc., Tulsa, OK, USA), with the level of significance set at $p < 0.05$. We used Student's t-test for dependent samples for data on noise measurement performed in same measurement point to test differences between noise levels during the day. Student's t-test for independent samples was used to test the differences in noise levels between the measurement points in the urban center and suburban residential area. As Kolmogorov-Smirnov test showed deviation from normal distribution of data, we used a nonparametric test for independent samples, Mann-Whitney U-Test. We also performed multiple regression analysis to determine the effects of socioeconomic characteristics and noise exposure on mental health.

Results

Noise Measurements

Noise measurements performed in schoolyards in the urban center showed that average noise levels, LAeq, 8 h ranged from 60 ± 1 to 65 ± 1 dBA, which was above 55 dBA – the WHO treshold for community noise. Noise levels LAeq, 16 h on crossroads near schools, which are part of the residential area, ranged from 59 ± 2 to 73 ± 2 dBA, also above of the WHO treshold (65 dBA). Statistical analysis of data for LAeq, 8 h showed that there were no significant changes in the noise level during the day. Noise measurements in the suburban residential area showed that LAeq, 8 h in the schoolyards ranged from 48 ± 1 to 54 ± 1 dBA; LAeq, 16 h on crossroads nearby schools were in range from 48 ± 1 to 53 ± 4 dBA (Fig. 1). There were no significant changes in noise levels during the day ($t = 0.89$; $p = 0.390$). However, LAeq, 16 h showed significant changes between noise levels measured at 10 am and 6 pm, noon and 6 pm, 3 and 6 pm, in both the urban center and the suburban area ($t = 2.470$; $p = 0.027$). Noise level values in the central part of the city, the residential-administrative-market area, were above the WHO guidelines (55 dBA for the schoolyard and 65 dBA for crossroads), but noise levels in the suburban residential area were below the WHO guidelines (Table 1). The significant difference between noise levels in these two different areas is very important for the assessment of exposure (Table 1).

Participants

After the exposure assessment, taking into account the WHO guideline values for schoolyards (55 dBA), we grouped the participants in two study

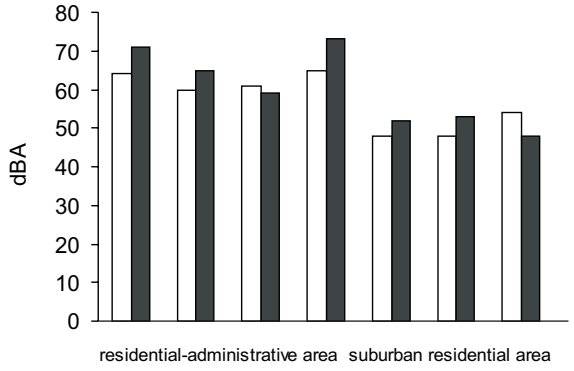

Figure 1. Average noise levels in urban center of Skopje, Macedonia. Open bars – LAeq, 8 h; closed bars – LAeq, 16 h.

groups: school children exposed to LAeq, 8 h >55 dBA (n=266; 130 boys and 136 girls) and school children exposed to LAeq, 8 h <55 dBA (n=263; 134 boys and 129 girls). The average age of the participants was 10.5 years, all of them fourth graders in primary schools. Assessment of the influence of socioeconomic characteristics was performed on 221 participants, 163 participants from the study group exposed to LAeq, 8 h >55 dBA and 158 participants from the study group exposed to LAeq, 8 h <55 dBA. The rest of the participants were excluded because they did not answer the questionnaire on socioeconomic characteristics.

Psychological Testing

Children exposed to elevated noise level had significant decrease in attention and social adaptability, as well as a significant increase in opposite behavior (Table 2). To test for confounding factors for mental health disorders, such as socioeconomic characteristics of the subjects we used the multiple regression as a model for analyzing the influence of three independent variables (education, employment of parents, and housing) on indicators for mental health of children as dependent variables (Table 3 and 4). Children exposed to LAeq, 8 h >55 dBA had very poor relation between psychosocial effects and socioeconomic characteristics (correlation coefficient 0.141-0.303). Children exposed to LAeq, 8 h <55 dBA also had very poor relation between examined variables and parent's education, employment, and housing (Table 4).

Table 3. Socioeconomic characteristics of examinees

Determinants of socioeconomic status	No. (%) of children exposed to LAeq*, 8 h>55 dBA† (n=163)	No. (%) of children exposed to LAeq, 8 h<55 dBA (n=158)
Housing conditions:		
under minimum (<16 m^2 per family member)	55 (34)	34 (22)
above minimum	108 (66)	124 (78)
Parent's education:		
primary school	21 (12)	1 (1)
secondary school	84 (52)	104 (66)
university education	58 (35)	53 (33)
Parent's employment:		
none	18 (11)	11 (8)
one parent	57 (36)	56 (35)
both parents	88 (52)	91 (57)

*LAeq, 8 h – average equivalent sound level for 8 hours in schoolyard (7 am to 3 pm).
†dBA – levels on a decibel scale of noise measured using frequency-dependent weighting.

Table 4. Multiple regression analysis of socioeconomic status, noise exposure, and psychological characteristic

Psychological effects	Children exposed to LAeq*, 8 h>55 dBA† (n=163)	Children exposed to LAeq, 8 h<55 dBA (n=158)
Anxiety	R=0.141‡	R=0.204
Attention	R=0.270	R=0.286
Hyperactivity	R=0.192	R=0.050
Social adaptability	R=0.303	R=0.312
Opposing behavior	R=0.218	R=0.278

*LAeq, 8 h – average equivalent sound level for 8 hours in schoolyard (7 am to 3 pm).
†dBA – levels on a decibel scale of noise measured using frequency-dependent weighting.
‡R – the coefficient of multiple correlation.

Discussion

We found that the children who live and study in the residential-administrative-market area were exposed to elevated noise levels, according to the WHO guidelines for prevention of adverse health noise effects (1,2). The noise was continuous, with significant

Table 1. Total noise (mean±SD, dBA) in urban center of Skopje*

Exposure	Residential administrative area	p†	Suburban residential area
LAeq, 8 h‡	62.5±2.4	0.004	50±3.5
LAeq, 16 h§	67±6.3	0.020	51±2.6

*dBA – levels on a decibel scale of noise measured using frequency-dependent weighting.
†t-test for independent variables.
‡LAeq, 8 h – average equivalent sound level for 8 hours in schoolyard (7 am to 3 pm).
§LAeq, 16 h – average equivalent sound level for 16 hours on crossroads nearby schools (6 am to 10 pm).

Table 2. Data analysis of psychological testing for study groups (mean±SD)

Psychological effects	Children exposed to LAeq*, 8 h>55 dBA†(n=266)	p‡	Children exposed to LAeq, 8 h<55 dBA (n=263)
Anxiety	23.8±6.77	0.110	22.9±8.38
Attention	23.4±5.39	0.031	24.1±6
Hyperactivity	11.7±5.3	0.216	11.6±5.62
Social adaptability	28.2±5.45	0.029	28.9±5.9
Opposite behavior	10.2±5.32	0.001	8.83±4.17

*LAeq, 8 h – average equivalent sound level for 8 hours in schoolyard (7 am to 3 pm).
†dBA – levels on a decibel scale of noise measured using frequency-dependent weighting.
‡Mann-Whitney U-Test.

decrease in evening hours, but still above the WHO guideline values. Children who live and study in the suburban residential area were exposed to noise levels below WHO guidelines. Since we found significant differences between noise levels of the residential-administrative-market-area and the suburban residential area, we decided to split the subjects into two study groups, according to the WHO guidelines for noise levels in schoolyards: study group exposed to noise LAeq, 8 h > 55 dBA and study group exposed to LAeq, 8 h < 55 dBA.

We did not find significant differences in anxiety between children exposed to LAeq, 8 h > 55 dBA and those exposed to LAeq, 8 h < 55 dBA, indicating that chronic noise exposure is not subjectively stressful. Adaptive behaviors may reduce the immediate stress response, but the coping process itself may have adverse health effect, measured as self-reported stress. Haines et al (8) found that children chronically exposed to high levels of aircraft noise had higher levels of perceived stress even after adjustment for socioeconomic characteristics. They showed that school children chronically exposed to aircraft noise had higher levels of self reported stress, paralleled by elevated stress hormone secretion and raised blood pressure. Basic data for anxiety did not differ among study groups exposed to different noise levels (8).

School children exposed to LAeq, 8 h > 55 dBA had significantly decreased attention in comparison with those exposed to the noise level LAeq, 8 h < 55 dBA. Noise exposure can cause cognitive impairments, such as decreased attention, but children may adapt to the noise interference during activities by filtering out the unwanted noise stimuli (7). They may use these strategies even when there is no noise, leading to their poorer ability to sustain attention in the classroom, which may in time continue to affect attention, even in the absence of noise exposure (3). Our results are in compliance with the theory of sustained attention. Lercher et al (10) also found the relation skip between residential noise exposure and decreased attention in subjects, after the adjustment for individual and social factors in children with a biological risk (preterm born children). They found a linear dose-response association in a large population study, replicated in two samples, between noise exposure and attention disorders. Evans et al (5,6) found that chronic noise exposure in young children causes psychological stress, measured as affective indicators. These effects occur among children who suffer no detectable hearing damage while living in the immediate vicinity of the airport. Haines et al (8) do not support the sustained attention theory, because the adjustment for sustained attention did not influence the significant association between the aircraft noise at school and reading comprehension. Attention process more rather than reading effects has been hypothesized as a mediator in noise-related memory impairments.

Decreased social adaptability and increased opposing behavior were significantly higher in children exposed to noise above the WHO guidelines. Noise exposure acting like an environmental stress factor, caused unwanted aversive changes in the affective state and communication problems, logically leading to social isolation. Evans et al (5,6) found a decreased social quality of life in children exposed to aircraft noise which persevered even after the adjustment for socioeconomic status. Lercher et al (10) found decreased social behavior in schoolchildren exposed to road traffic noise, using a teacher-rating questionnaire.

The limitations of the study include its cross-sectional design, small number of participants, and absence of prospective investigations. We need further prospective studies with more sensitive tests to determine the stress response in the exposed population.

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