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Noise sensitivity and dwelling characteristics affect the quality of sleep among schoolchildren

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ABSTRACT

The aim of the study was to assess the quality of sleep of schoolchildren from a central Belgrade municipality in relation to nighttime road traffic noise exposure, children's noise sensitivity and some dwelling characteristics. Children's noise sensitivity correlated significantly and directly with the time needed to fall asleep (Spearman's rho, ρ=0.103), feeling tired in the morning (ρ=0.172), reported poor quality of sleep (ρ=0.171), and being awoken by noise at night (ρ=0.091). Children sleeping in bedrooms facing the street reported poorer sleep quality, felt tired after awakening, reported being awoken by noise and never slept by open windows in comparison with children with bedrooms facing the quiet side of the building. Children residing in crowded apartments slept less and were more often awoken by noise compared to children from more spacious apartments. In conclusion, some dwelling characteristics and noise sensitivity may affect children's sleep quality, independently from age, gender, and noise exposure.

Keywords: Sleep, Noise Sensitivity, Children

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1. INTRODUCTION

Sleep is an active neurophysiological process essential for normal growth and development, daytime activities, well-being, and quality of life [1]. It is regulated by the circadian system and sleep-wake homeostasis synchronized by complex neurological pathways in the brainstem and the cerebral cortex [1].

Children's sleep affects their physical growth, behavior, and emotional development [2, 3]. Contrary to some expectations, sleep problems among children are not an exception; they seem to be rather common with the prevalence ranging from 20 to 30% and have been shown to impair child's behavior, school performance, attention and learning [1-5], hyperactivity or conduct problems at school and emotional problems [6], as well as family well-being [1].

Many factors have been investigated in association with sleep in children, both protective and detrimental ones. Researchers and practitioners generally agree that the so-called sleep hygiene or consistent bedtime routine plays the most important protective role for high quality of sleep, regularity of sleep patterns and the longer period of sleep at night [7-9]. On the other hand, numerous habits, such as the use of computer, phones, television, or other audio-visual devices in the bedroom at bedtime [7, 8], the consumption of tobacco or caffeine in the evening [7, 9], and the presence of intrusive light in the bedroom [7, 10], portray an image of an inadequate sleep environment at home.

Traffic noise is a well-known risk factor for sleep disturbances in both children and adults [11]. Noise exposure depends on several characteristics of the source itself, such as the type of the source, the time and the duration of exposure, sound levels, sound frequency, etc. Furthermore, it depends on the characteristics of the pathway of exposure, such as dwelling characteristics, including the orientation of the rooms, floor level, crowding, and window glazing. Finally, some individual characteristics, primarily noise sensitivity, may modulate the association between noise exposures and sleep problems.

The aim of the study was to assess the predictive role of noise sensitivity, dwelling characteristics and nighttime noise exposure on the quality of sleep in a large sample of urban schoolchildren from a central municipality in Belgrade, Serbia.

2. METHODS

2.1 Study sample

This cross-sectional study was carried out in eight public schools in a central Belgrade municipality of Stari Grad between September 2008 and June 2009. As described previously in detail [12, 13], about 2000 children aged 7 to 11 years and their parents were approached through school boards to join a large ecological survey aiming to estimate the effects of road-traffic noise on children's health, including blood pressure, sleep disturbances and executive functioning. Parents of 1150 children (57.5% response rate) granted permission for their children to participate in the study. Parents and children gave informed and written consent for participating in this study. The study was approved by the Ethics Committee of the Faculty of Medicine in Belgrade.

2.2 Questionnaire and sleep characteristics

Parents provided information about their children in a self-report questionnaire that included some basic characteristics, including child's age, gender (coded as: 0 – girl, 1 – boy), and child's sensitivity to noise (coded as: 0 – totally insensitive, 1 – insensitive, 2 – sensitive, and 3 – very sensitive to noise).

The following sleep characteristics were covered by the questionnaire: 1. Average duration of child's sleep during the night (hours) – this variable was further recoded into 0 – more than 8 hours, 1 – sleep duration 8 hours or less; 2. Average time needed for child to fall asleep (minutes) – this variable was further recoded into 0 – asleep within 30 minutes, 1 – 30 minutes or more needed to fall asleep; 3. Being awoken by noise – coded as 0 – no, 1 – yes; 4. Reported feeling after waking up in the morning, categorized as fully rested, rested, changeable, mostly tired, very tired; this variable was further recoded as: 0 – mostly rested or fully rested, 1 – changeable, mostly tired or very tired; 5. Reported sleep quality, categorized as excellent, good, changeable, poor, very poor; this variable was further recoded as: 0 – good or excellent, 1 – changeable, poor or very poor; and 6. Habit of sleeping by open windows, categorized as often, sometimes, never; this variable was further recoded as: 0 – often or sometimes, 1 – never.

2.3 Noise exposure and dwelling characteristics

Road-traffic noise levels were measured in the middle of all streets of the investigated municipality in 2008 using a Hand-held Noise Level Analyzer type 2250 "Brüel & Kjær". Leq was measured in two daytime intervals (between 8 and 10 a.m. and between 2 and 4 p.m.), one evening interval (between 6 and 8 p.m.), and two nighttime intervals (between 10 and 12 p.m., and between midnight and 2 a.m.). For the purpose of this study, only nighttime noise levels were assigned to all children's addresses. Children's noise exposure was categorized as: 0 – not exposed, 1 – exposed to nighttime noise above 56 dBA.

In addition, parents provided information about some dwelling characteristics, such as the orientation of child's bedroom, coded as: 0 – away from the street, 1 – facing the street; the position of the apartment, coded as: 0 – second floor or above, 1 – at or below first floor (including ground floor and sutterrain). Parents also reported the size of the apartment (square meters) and the number of tenants per apartment. These variables were used to calculate the average size of apartment per dweller, which was further recorded into: 0 – more than 16 m^2 per dweller, 1 – equal or less than 16 m^2 per dweller.

2.4 Statistical analysis

Descriptive statistic was presented as mean values and standard deviations for numeric variables, and as percents (relative numbers) for categorical variables. The differences by gender were compared using Student's t-test for parametric data and Mann-Whitney U test and Chi-square test for non-parametric data. Correlation between child's noise sensitivity level and sleep characteristics was analyzed by Spearman's correlation coefficients. Multiple logistic regression models were fitted to calculate odds ratios for the occurrence of sleep characteristics in relation to child's age, gender, noise sensitivity level, noise exposure and dwelling characteristics. SPSS 15.0 for Windows software was used for data analyses (SPSS Inc. 1989-2006).

3. RESULTS

The study was conducted on a sample of 1150 schoolchildren, aged 7 to 11 years. More than a half of all children were insensitive or totally insensitive to noise. Only about 30% of children were reported being sensitive to noise, and about 5% of boys and 7% of girls were highly sensitive to noise (Table 1).

Table 1. Basic characteristics and noise sensitivity level of the investigated schoolchildren by gender

Parameters		Boys	Girls	p value
Number of schoolchildren		555 (48.3%)	595 (51.7%)	
Age (months)		109.8±14.1	109.9±14.5	0.926*
Noise sensitivity level	Totally insensitive	70 (13.7%)	72 (12.9%)	0.734**
	Insensitive	255 (49.8%)	280 (50.2%)	
	Sensitive	160 (31.3%)	168 (30.1%)	
	Very sensitive	27 (5.3%)	38 (6.8%)	

* Student's t-test
** Pearson's chi-square test

The investigated boys and girls shared similar sleep characteristics. Girls and boys sleep on average 9 hours per night, and fall asleep within 13-14 minutes. Less than 20% of the children reported the following sleep disturbances, such as sleeping 8 hours or less per night, needing 30 minutes or more to fall asleep, feeling tired or very tired in the morning, and never sleeping by open windows. Less than 10% of children reported poor or very poor sleep quality, and only about 1-2% of children reported being awoken by noise at night. The differences between boys and girls were not statistically significant (Table 2).

Table 2. Sleep characteristics of the investigated schoolchildren by gender

Parameters	Boys	Girls	p value
Average time needed to fall asleep (minutes)	14.2±11.4	13.4±9.4	0.562*
30 minutes or more needed to fall asleep	75 (14.0%)	80 (13.8%)	0.923**
Average sleep duration (hours)	9.3±0.9	9.3±0.9	0.625*
Sleep duration 8 hours or less	94 (17.1%)	107 (18.0%)	0.672**
Being awoken by noise	12 (2.2%)	7 (1.2%)	0.187**
Feeling tired or very tired in the morning	93 (16.8%)	112 (18.9%)	0.376**
Reported poor or very poor sleep quality	41 (7.5%)	30 (5.1%)	0.095**
Never sleeps by open windows	92 (17.0%)	106 (18.1%)	0.624**

* Mann-Whitney U test
** Pearson's chi-square test

The average nighttime road traffic noise level in the investigated streets was 60.5±8.0 dBA, ranging from 42 to 84 dBA, and almost two thirds of the investigated population was exposed to levels above 56 dBA (data not shown).

Schoolchildren shared similar dwelling characteristics. More than a half of all children sleep in bedrooms facing the street, and reside in apartments whose size is equal or below 16 m^2 per dweller; more than a third of all children reside in apartments located at the first floor, on the ground floor or below ground (sutterrain). The differences between boys and girls were not statistically significant (Table 3).

Table 3. Dwelling characteristics of the investigated schoolchildren by gender

Parameters	Boys	Girls	p value
Bedroom windows facing the street	283 (51.5%)	308 (52.6%)	0.687*
Apartment at or below first floor	182 (35.5%)	213 (37.8%)	0.473*
Apartment size ≤ 16 m^2 per dweller	283 (52.0%)	291 (50.0%)	0.498*

* Pearson's chi-square test

Children's noise sensitivity level correlated directly and significantly with feeling tired in the morning (Spearman's rho, ρ=0.172), reported poor quality of sleep (ρ=0.171), the time needed to fall asleep (ρ=0.103), and being awoken by noise at night (ρ=0.091) (data not shown). These correlations were similar among boys and girls.

Odds ratios and 95% confidence intervals for the occurrence of the investigated sleep characteristics in relation to gender, age, noise sensitivity level, noise exposure, and dwelling characteristics are presented in Tables 4 and 5.

Children who reside in apartments sized ≤ 16m^2 per dweller had almost two times higher odds of sleeping eight hours or less, and almost four times higher odds of being awoken by noise at night in comparison to children from more spacious apartments. Children who sleep in bedrooms facing the street had almost eleven times higher odds of being awoken by noise at night in comparison to children sleeping in bedrooms facing the quiet side of the building. These associations were independent from child's age, gender, noise sensitivity level, noise exposure and other dwelling characteristics. Children's age was directly related to the occurrence of shorter sleep duration (Table 4).

Noise sensitivity level was not an independent predictor of the above-mentioned sleep characteristics (Table 4).

Table 4. Odds ratios (95% confidence intervals) for the occurrence of: sleep duration 8 hours or less, 30 minutes or more needed to fall asleep, and being awoken by noise in relation to gender, age, noise sensitivity level, noise exposure and dwelling characteristics

Parameters		Sleep duration 8 hours or less	30 minutes or more needed to fall asleep	Being awoken by noise
Gender – male		0.903 (0.606-1.345)	1.039 (0.679-1,590)	1.321 (0.460-3.799)
Age (months)		1.041 (1.025-1.056)	1.003 (0.988-1.018)	1.010 (0.974-1.048)
Noise sensitivity level	Totally insensitive	1.000	1.000	1.000
	Insensitive	1.293 (0.651-2.569)	0.830 (0.412-1.670)	n.c.
	Sensitive	1.837 (0.906-3.722)	1.482 (0.735-2.987)	n.c.
	Very sensitive	1.912 (0.708-5.164)	1.510 (0.561-4.067)	n.c.
Exposed to nighttime noise above 56 dBA		0.767 (0.509-1.157)	0.995 (0.637-1.555)	1.108 (0.364-3.371)
Bedroom windows facing the street		1.020 (0.682-1.525)	1.108 (0.719-1.708)	10.631 (1.377-82.077)
Apartment at or below first floor		0.896 (0.583-1.379)	0.977 (0.613-1.558)	1.254 (0.412-3.816)
Apartment size ≤ 16m^2 per dweller		1.899 (1.255-2.874)	1.093 (0.709-1.684)	3.859 (1.063-14.002)

n.c. – not calculated

Children's noise sensitivity level was a significant and independent predictor for feeling tired in the morning and reported poor sleep quality, but failed to be an independent predictor for never sleeping by open windows. Children reported to be noise sensitive had almost three times higher odds for feeling tired or very tired in the morning and almost nine times higher odds for reported poor or very poor sleep quality.

Children reported to be very noise sensitive had five times higher odds for feeling tired or very tired in the morning and almost nine times higher odds for reported poor or very poor sleep quality (borderline significant) (Table 5).

Children who reside in apartments sized ≤ 16m^2 per dweller had almost two times higher odds of feeling tired or very tired in the morning in comparison to children from more spacious apartments. Children who sleep in bedrooms facing the street had almost two times higher odds of reported poor or very poor sleep quality, and by 50% higher odds of never sleeping by open windows in comparison to children whose bedrooms are facing the quiet side of the building. Children who live in apartments at first floor or below had by 50% higher odds of never sleeping by open windows in comparison to children from apartments at higher levels. These associations were independent from child's age, gender, noise sensitivity level, noise exposure and other dwelling characteristics (Table 5).

Children's age and gender were not related to any of the above-mentioned sleep characteristics (Table 5).

Table 5. Odds ratios (95% confidence intervals) for the occurrence of: felling tired in the morning, reported poor sleep quality, and never sleeping by open windows in relation to gender, age, noise sensitivity level, noise exposure and dwelling characteristics

Parameters		Feeling tired or very tired in the morning	Reported poor or very poor sleep quality	Never sleeps by open windows
Gender – male		1.808 (0.551-1.185)	1.126 (0.628-2.020)	1.028 (0.699-1.511)
Age (months)		1.003 (0.990-1.017)	1.003 (0.983-1.024)	0.996 (0.982-1.009)
Noise sensitivity level	Totally insensitive	1.000	1.000	1.000
	Insensitive	1.659 (0.804-3.420)	6.141 (0.817-46.160)	1.041 (0.554-1.956)
	Sensitive	2.715 (1.305-5.468)	8.898 (1.174-67.455)	1.300 (0.680-2.486)
	Very sensitive	5.400 (2.174-13.411)	8.890 (0.953-82.951)	1.755 (0.719-4.284)
Exposed to nighttime noise above 56 dBA		1.109 (0.742-1.656)	0.986 (0.537-1.813)	1.033 (0.690-1.547)
Bedroom windows facing the street		1.160 (0.787-1.710)	1.919 (1.027-3.583)	1.506 (1.015-2.235)
Apartment at or below first floor		1.245 (0.830-1.868)	0.926 (0.486-1.764)	1.497 (1.008-2.222)
Apartment size ≤ 16 m^2 per dweller		1.709 (1.162-2.513)	1.691 (0.917-3.120)	1.115 (0.753-1.652)

4. DISCUSSION

Nighttime noise exposure is one of the most detrimental environmental factors for human sleep. The most common source of that background noise is road traffic. This type of noise was related to several forms of sleep disturbances in children: shorter duration of sleep [10, 14], prolongation of the time needed to fall asleep [15], sleep awakenings [14], modification of sleep stages [14], self-reported poor quality of sleep [10, 14, 15], tiredness after sleep [10], self-reported bruxism (i.e. involuntary teeth grinding during sleep) [16], and even heart rate changes and vasoconstriction [14]. Furthermore, noise exposure impaired objective sleep parameters, measured by polysomnogram [17, 18], or sleep logs and wrist-actigraphy [15].

Recent studies report similar effects of noise on sleep. For example, nighttime road traffic noise was associated with sleeping problems, difficulties with falling asleep, and some behavioral problems among 10-year old German children [19]. High traffic density was significantly associated with sleep disturbances and attention disorders among 7-14- year-old children in Poland [20]. A significant association between road traffic noise and shorter sleep duration was reported among 7-year old girls in Norway, but not among boys [21].

Various noise sources, such as aircraft and rail noise caused similar effects on sleep parameters as did road traffic noise, except that the latency to deep sleep and the amount of deep sleep were more intensely affected by rail traffic noise in comparison to the other noise sources [18]. This brings about the concurrent presence of several noise sources at home. Looking beyond the outdoor sources, that are often in research focus, one must keep in mind the abundance of indoor sources as well, including appliances, audio-visual devices, other humans, animals, etc. As demonstrated in an Austrian study, noise exposure levels alone cannot account for reported sleep disturbances in children residing in complex acoustic environments [22].

The presented study emphasizes the importance of dwelling characteristics for sleep outcomes. The results show that the orientation of the child's bedroom, the floor level, and the apartment size are significantly related to the shorter duration of sleep, awakening by noise, and feeling tired in the morning. In a large survey of the adult population in Brussels, participants residing in noisy areas and sleeping in bedrooms facing the street reported more noise-related sleep problems, without the effect on sleepiness in the morning or on sleep variables registered with actigraphy [23]. Bedroom orientation, window glazing, floor level, and apartment crowding are relevant for noise exposure, but further studies are needed to confirm the hypothesis that noise-induced sleep problems occur predominantly among children and adults living in inadequate dwellings.

To the authors' opinion, noise sensitivity in children is a neglected topic in environmental research. In adults, noise sensitivity has been shown to mediate the effects of noise on noise annoyance [24], sleep loss [25], and reported physical and mental health [26], among others. In children, noise sensitivity contributed significantly to sleep problems, reported either by children alone or their mothers [22]. Noise sensitivity scales measure the global sensitivity and the state in various aspects of daily lives [27, 28]. Addressing noise sensitivity from the developmental point of view should accompany the genetic, medical, physiological and psychological aspects of this trait [29]. Future studies should propose a reliable, universal, comprehensible self-assessment tool for children of different ages.

The presented study has several limitations. First, many characteristics were not taken into account. These include the above-mentioned habits that provoke sleep problems, such as TV watching, using a computer or playing games at bedtime [7-8], as well as some useful habits that improve sleep in children, such as physical activity and sleep hygiene [7-9]. Second, we failed to assess the consumption of caffeine or energy drinks, and tobacco use, which may affect children's sleep [7-8]. Nevertheless, we doubt that such practices are common among schoolchildren of the selected age. Third, we did not control for parental characteristics, for example, education, employment, household income or socio-economic status, as they may affect family relationships as well as the dwelling characteristics and consequently noise exposure. Some of those parameters were relevant in our previous study in Belgrade [30].

Fourth, we did not ask whether children sleep alone in the room or share a bedroom with siblings or parents. It may come as a surprise that room sharing or bed sharing came about in a third of the investigated 6-13-year-old children in Belgium [10]. Fifth, we should have asked the parents about their sleep problems and sleeping habits, bearing in mind that children may adopt their parents' sleep patterns and sleep hygiene in the family environment. Finally, we are aware that the results of the study cannot be generalized to other populations, without considering possible social and cultural differences, practices, and expectations regarding children's sleep.

5. CONCLUSIONS

Children's reported noise sensitivity level was a significant predictor for feeling tired in the morning and reported poor sleep quality. Some dwelling characteristics, such as apartment size, floor level, and the orientation of bedrooms may also affect children's sleep, in terms of the duration of sleep, awakening by noise, and tiredness in the morning, independently from age, gender, and noise exposure. Public health measures in the investigated municipality of Belgrade should primarily comprise the decrease of nighttime noise levels, both from traffic and from other environmental sources. In addition, the community should be informed about the means of reducing noise exposure by improving or adapting some dwelling characteristics in an economical and effective way.

6. ACKNOWLEDGEMENTS

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