Urban road-traffic noise and blood pressure in school children

Goran Belojevic[1]*, Branko Jakovljevic[1], Katarina Paunovic[1], Vesna Stojanov[2], Jelena Ilic[1]

[1] School of Medicine, Institute of Hygiene and Medical Ecology, Dr Subotica 8, 11000 Belgrade, Serbia

[2] Center for Arterial Pressure Disorders, Clinical Center of Serbia, Pasterova 2, 11000 Belgrade, Serbia

*corresponding author: gogibel@eunet.yu

INTRODUCTION

Blood pressure regulation might be disturbed during a long term exposure to noise through the raise of circulatory stress hormones: adrenaline, nor-adrenaline and cortisol (Maschke et al. 2000). Several epidemiological studies have shown that road-traffic noise might increase the risk of arterial hypertension (RR between 1.5 and 3.0) in adults who live in areas with daytime average sound pressure levels exceeding 65 dB(A) (Babisch 2006). However, the results of the studies on noise exposure and children's blood pressure are less consistent. This association was found to be negative and non-significant (Lercher 1992), negative and significant (van Kempen et al. 2006), positive and borderline significant (Evans et al. 2001), or positive and significant (Regecova & Kellerova 1995; Belojevic et al. 2008).

There are several possible reasons for inconsistency in the results of studies on road traffic noise and blood pressure in children: noise exposure was assessed in different settings – either at home or at school or at kindergartens, the children were of different age (ranging from preschool to school age), road traffic noise was sometimes combined with other sources of noise (aircraft, railway) and daytime noise level was predominantly used as a noise exposure indicator at home instead of nighttime noise level. We used the nighttime noise as an exposure indicator at home in our previous study on preschool children (Belojevic et al. 2008), as children spend a larger part of their evening and nighttime sleeping at home than the adults (Xue et al. 2004). The same noise exposure design was applied in this study.

The aim of this study was to investigate the effects of urban road-traffic daytime noise around schools and nighttime noise around residences on blood pressure levels of school children.

METHODS

Study sample

A cross-sectional study was performed on school children aged 7–11 years, who attended 6 primary schools in Belgrade. Children came to school at 8 a.m. and stayed there for 4-5 hours. Parents were informed and gave written consent for participation in the study. Out of 856 interwieved parents, 557 (65 %) returned the questionnaires with approval for examination. The inclusion criteria for the study sample were: living on the present address for three or more years, and the orientation of child's room towards the streets. The exclusion criterion was the presence of chronic diseases affecting arterial blood pressure (diabetes mellitus and/or renal diseases). After applying the inclusion and exclusion criteria there were 163 and 3 subjects respectively, who were not included in the sample. Thus, the final sample consisted of 391 school children (186 boys and 205 girls).

Noise measurements

Equivalent noise levels (L_{eq}) were measured during night in front of children's residences and during day in front of schools. Noise Level Analyser type 4426 “Brüel & Kjær” was used, according to recommendations of the International Standard Organization for the measurement of community noise (ISO 1982). Equivalent noise levels (L_{eq}) were measured in two night intervals in front of children’s residences: between 22:00 and 23:30. and between 24:00 and 1.30 a.m. In front of each school noise measurements were performed in two daily periods (9.00h-10.30h and 11:30h-13:00h). Time interval of each measurement was 15 minutes; the speed of sampling was 10 per second, with 9000 samples collected per measurement. From the obtained L_{eq} a composite nighttime L_{eq} was calculated for each street and a daytime L_{eq} for each school.

A residence was regarded noisy if L_{eq} exceeded 45 dB(A) during night and quiet if the L_{eq} was ≤ 45 dB(A). School was regarded noisy if L_{eq} exceeded 60 dB(A) during day and quiet if the L_{eq} was ≤ 60 dB(A). The children were divided into four groups according to noise exposure: 1. Quiet residence and quiet school; 2. Quiet residence and noisy school; 3. Noisy residence and quiet school, and 4. Noisy residence and noisy school.

Questionnaire

The questionnaire consisted of two segments. The first part comprised general socio-demographic data: child's age, sex, birth by order, parents' education (1-elementary school; 2-secondary school; 3- college; 4 - faculty), parental employment, marital status, monthly income (1-insufficient; 2- sufficient; 3- more than sufficient), apartment size, number of dwellers, floor, period of residence and orientation of a bedroom towards the street.

The second part of the questionnaire consisted of questions on family history of arterial hypertension and diseases related to AH (diabetes mellitus, renal diseases).

Anthropometric measuring

Body height and weight were measured in the morning, in light clothes, without shoes. Body mass index (BMI) was calculated from body weight and height. Software available on the website of the Centers for Disease Control and Prevention was used to calculate body mass index-for-age percentile (Kuczmarski et al. 2000).

Blood pressure measuring

Children's blood pressure was measured with mercury sphygmomanometer. Cuff size of 11×27 cm was used according to arm measurement criteria (Kirkendall et al. 1981). The measurements were performed after a 15 minute rest, in a sitting position, with a child's right arm at heart level. Two measurements were performed on the right arm with five-minute interval. If the difference between measurements exceeded 5 mmHg, the third measurement was performed and mean values of systolic and diastolic arterial blood pressure were calculated.

Statistical analysis

Descriptive statistic is presented as mean values ± standard deviation (SD). Differences between groups in parametric data were tested using Student's t-test and one-way ANOVA [followed by Least Significant Difference Test (LSD) post hoc analysis]. Mann Whitney U-test and X^2 test were used for nonparametric data. Pearson correlation analysis was performed to test the association between variables from the questionnaire and children's blood pressure. Based on the results of univariate analyses, variables significantly related to blood pressure were included in a multiple linear regression model.

RESULTS

Concerning the basic characteristics of the study population, boys had significantly higher body weight, BMI-for-age-percentile and systolic pressure compared to girls Table1).

Table 1: Basic characteristics of boys and girls from the study population (mean±standard deviation)

Parameter	Boys	Girls	Total	p value
Number	186	205	391	
Age (months)	109.53±13.23	109.70±14.49	109.62±13.89	0.904*
Body weight (kg)	35.56±9.28	33.18±7.63	34.29±8.51	0.006*
Body height (cm)	138.80±8.96	137.48±9.77	138.10±9.41	0.176*
BMI-for-age-percentile	60.73±29.10	50.22±29.00	55.13±29.48	<0.0001**
Systolic pressure (mmHg)	103.53±8.74	98.54±8.59	100.86±9.00	<0.0001*
Diastolic pressure (mmHg)	58.37±7.79	57.47±7.37	57.89±7.57	0.253*

* Student’s t-test
** Mann-Whitney U test

Correlation analysis between relevant variables from the questionnaire and children's blood pressure levels showed that body weight, body height, BMI-for-age percentile, family income and family history of hypertension were significantly and positively related to children's systolic pressure. Concerning diastolic pressure we found a significant negative correlation with age and a positive correlation with BMI-for-age percentile (Table 2).

Table 2: Results of the Pearson correlation analysis between variables from the questionnaire and children's cardiovascular parameters (N=391)

Parameter	Mean systolic pressure	Mean diastolic pressure
Age (months)	0.033	-0.128*
Birth by order	-0.057	-0.015
Body weight (kg)	0.366**	0.098
Body height (cm)	0.192**	0.016
BMI-for-age-percentile	0.345**	0.176**
Mother’s education	0.028	-0.054
Family income	0.126*	0.048
Years of residence	0.072	0.025
Apartment size per dweller	0.007	-0.037
Floor	0.050	0.057
Family history of hypertension	0.161**	0.051

* p<0.05 (2-tailed)
** p<0.01 (2-tailed)

Systolic blood pressure was significantly higher (4-9 mm Hg, on average) among children from noisy schools and quiet residences and from both noisy environments, compared to children from both quiet environments. There were no significant differences in diastolic pressure between children from noisy schools and/or noisy residents and from both quiet environments. Gender distribution, average body weight, height and body mass index-for-age-percentile were similar in four investigated groups. Children from noisy residences and quiet schools were older than children from both quiet environments (Table 3).

Table 3: Comparison of the studied subgroups of children in relation to age, anthropometric parameters and blood pressure (mean±standard deviation); Q=quiet; N=noisy; R=residence; S=school

Parameter	QR*-QS†	QR*-NS§	NR‡-QS†	NR‡-NS§	p value
Number	42	65	45	239	
Boys (%)	38.1	55,4	48.9	46.9	0.364**
Age (months)	108.95±16.66	106.37±12.01	118.93±15.34††	108.87±12.88	<0.0001‡‡
Body weight (kg)	34.17±7.69	34.831±8.65	36.63±10.31	33.73±8.20	0.210‡‡
Body height (cm)	136.92±9.19	137.292±8.27	141.87±11.56	137.82±9.20	0.061‡‡
BMI-for-age-percentile	59.74±29.56	61.72±28.18	51.53±33.11	53.17±28.93	0.118‡‡
Systolic pressure (mmHg)	96.59±8.61	105.11±9.16††	99.52±10.32	100.64±8.32††	<0.0001‡‡
Diastolic pressure (mmHg)	57.62±6.56	60.18±7.36	58.49±6.72	57.18±7.84§§	0.039‡‡

* $L_{eq,night} \leq 45$ dB(A)
† $L_{eq,day} \leq 60$ dB(A)
‡ $L_{eq,night} \geq 45$ dB(A)
§ $L_{eq,day} \geq 60$ dB(A)
** X^2 test
†† p<0.001 vs. QR-QS; LSD post hoc analysis
‡‡ One-way ANOVA
§§ p<0.005 vs. QR-NS; LSD post hoc analysis

Multiple regression, after allowing for gender, age, BMI-for-age percentile, family history of hypertension and family income, showed significant positive correlation between noise exposure at school and children's systolic pressure (Table 4).

Table 4: Multiple regression analysis between systolic pressure (dependent variable) and relevant variables in the study population of children (n=391)

Parameter	B	95 % Confidence Interval for B		Standard error	t	p value
Noise exposure at school*	3.413	1.903	4.923	0.769	4.438	<0.0001
Gender	-2.114	-3.317	-0.911	0.613	-3.449	0.001
Age (months)	0.064	0.021	0.107	0.022	2.943	0.003
BMI-for-age-percentile	0.111	0.091	0.131	0.010	10.900	<0.0001
Family history of hypertension	-1.325	-3.735	1.086	1.228	-1.079	0.281
Family income	-0.657	-1.885	0.572	0.626	-1.049	0.294
Constant	88.266	80.393	96.139	4.011	22.007	<0.0001

*Coded as: 1 – quiet school; 2 – noisy school

Diastolic blood pressure was significantly and positively correlated only with BMI-for-age-percentile (Table 5).

Table 5: Multiple regression analysis between diastolic pressure (dependent variable) and relevant variables in the study population of children (n=391)

Parameter	B	95 % Confidence Interval for B		Standard error	t	p value
Noise exposure at school*	-0.413	-1.764	0.938	0.688	-0.600	0.549
Gender	0.122	-0.954	1.197	0.548	0.222	0.824
Age (months)	-0.037	-0.075	0.002	0.020	-1.884	0.060
BMI-for-age-percentile	0.050	0.032	0.068	0.009	5.469	<0.0001
Family history of hypertension	-1.113	-2.625	0.398	0.770	-1.446	0.149
Family income	-0.471	-1.575	0.632	0.562	-0.838	0.402
Constant	62.595	56.059	69.132	3.329	18.800	<0.0001

*Coded as: 1 – quiet school; 2 – noisy school
Constant – the value of y in the multiple regression equation when all the independent values are zero

Regression coefficient (B) – for the respective variable is calculated in the multiple regression equation by minimizing the sum of the squares of the differences from the observed and predicted outcome variables.

SE – standard error

t-value is the regression coefficient estimate divided by its SE

DISCUSSION

In this study on school children we found that systolic blood pressure was higher in children exposed to nighttime noise at home of L_{eq} > 45 dB(A) and to day time noise around schools of L_{eq} > 60 dB(A) compared to those exposed to noise at home of L_{eq} ≤ 45 dB(A) and to noise schools of L_{eq} ≤ 60 dB(A). Noise around schools was a significant independent factor for children's systolic pressure in a multiple regression analysis, after allowing for confounders.

These effects may be of a temporary nature and it is unknown whether the effects of noise on blood pressure are reversible if exposure to noise ceases. It is difficult to indicate whether and to what extent slight increases in children's blood pressure can cause possible health risks in later life, although there are evidences that elevations of blood pressure in childhood may predict hypertension in young adults (Bao et al. 1995).

Our results are in accordance with our previous study (Belojevic et al. 2008) in which mean systolic pressure was significantly higher (5 mm Hg on average) in pre-school children from noisy kindergartens and homes ($L_{eq,day}$ > 60 dB(A) and $L_{Aeq,night}$ > 45 dB(A), respectively) than in children from the quiet environments ($L_{eq,\ day}$ ≤ 60 dB(A) and $L_{eq,\ night}$ ≤ 45 dB(A), respectively). The results of our study are partially in accordance with the results from Bratislava study on pre-school children (Regecova & Kellerova 1995) and with the Inn Valley study (Evans et al. 2001). In the Bratislava study significantly higher systolic and diastolic blood pressure readings were found in children from homes and/or kindergartens exposed to traffic noise of L_{eq24h} > 60 dB compared to those from less exposed areas ($L_{eq,24h}$ ≤ 60 dB). The noise exposure indicator was 24 h L_{eq} at homes and kindergartens. The Inn Valley study found marginal and borderline significant effect of noise on elevated resting systolic blood pressure in children of 4th grade, who were exposed to high noise levels (L_{dn} >60 dB) from road and railway noise, compared to less exposed children (L_{dn} < 50 dB). Opposite to our results are the findings of the London and Amsterdam study (Van Kempen et al. 2006) and the Tyrol study (Lercher 1992). The London and Amsterdam study showed negative and significant association between day time road traffic noise at schools and systolic blood pressure. However, nighttime aircraft noise was significantly and positively associated with blood pressure. The Tyrol study showed lower, non-significant, blood pressure readings in children aged 8-12 years and exposed to highway noise of $L_{eq,24h}$ ≥ 64 dB(A) compared to control group living in quiet areas ($L_{eq,24h}$ < 50 dB(A).

Limitations of the study include a relatively low response rate of 65 %, although parents and the school boards were fully informed about the study. Secondly, we did not check for hearing acuity of the children. Third, with a two factorial design we could not investigate a dose response relationship. Fourth, we did not control the insulation of children's homes and schools.

CONCLUSIONS

The results of our study have showed that systolic blood pressure was significantly higher in children exposed to nighttime noise at home of L_{eq} > 45 dB(A) and to day time noise around schools of L_{eq} > 60 dB(A), compared to those exposed to noise at home of L_{eq} ≤ 45 dB(A) and to noise at schools of L_{eq} ≤ 60 dB(A). In a multiple regression analysis, noise around schools was a significant independent factor for children's systolic pressure, after allowing for confounders.

REFERENCES

Babisch W (2006). Transportation noise and cardiovascular risk: updated review and synthesis of epidemiological studies indicate that the evidence has increased. Noise & Health 8: 1-29.

Bao W, Threefoot SA, Srinivasan SR, Berenson GS (1995). Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: the Bogalusa Heart Study. Am J Hypertens 8: 657-665.

Belojevic G, Jakovljevic B, Stojanov V, Paunovic K, Ilic J (2008). Urban road traffic noise and blood pressure and heart rate in preschool children. Environ Int 34: 226-231.

Evans GW, Lercher P, Meis M, Ising H, Kofler W (2001). Community noise exposure and stress in children. J Acoust Soc Am 109: 1023-1027.

ISO, International Organization for Standardization (1982). Acoustics—description and measurement of environmental noise—Part l, Basic quantities and procedures. International Standard Organization. ISO 1996-1. Geneva.

Kirkendall WM, Feinleib M, Freis ED, Mark AL (1981). Recommendations for human blood pressure determination by sphygmomanometers. Subcommittee of the AHA Postgraduate Education Committee. Hypertension 3: 510A–519A.

Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL (2000). CDC growth charts: United States. Advance data from vital and health statistics; no. 314. Hyattsville, MD: National Center for Health Statistics.

Lercher P (1992). Auswirkungen des Straßenverkehrs auf Lebensqualität und Gesundheit. Transitverkehrs-Studie, Teil II. Innsbruck: Amt der Tiroler Landesregierung, Landesbaudirektion, Landessanitätsabteilung.

Maschke C, Rupp T, Hecht K (2000). The influence of stressors on biochemical reactions – a review of present scientific findings with noise. Int J Hyg Environ Health 203: 45-53.

Regecova V, Kellerova E (1995). Effects of urban noise pollution on blood pressure and heart rate in preschool children. J Hypertension 13: 405-412.

van Kempen E, van Kamp I, Fischer P, Davies H, Houthuijs D, Stellato R, Clark C, Stansfeld S (2006). Noise exposure and children's blood pressure and heart rate: the RANCH project. Occup Environ Med 63: 632-639.

Xue J, McCurdy T, Spengler J, Ozkaynak H (2004). Understanding variability in time spent in selected locations for 7-12 year old children. J Exp Anal Environ Epidemiol 14: 222-233.