URBAN NOISE AND BLOOD PRESSURE OF THE POPULATION – A SYSTEMATIC REVIEW OF STUDIES IN BELGRADE

GRADSKA BUKA I KRVNI PRITISAK STANOVNIŠTVA – SISTEMATSKI PREGLED ISTRAŽIVANJA U BEOGRADU

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Summary

The Belgrade team for biological effects of noise, comprising experts in the fields of hygiene and cardiology, has carried out population studies in Belgrade on the sample of 2503 adults, 328 pre – school children and 1113 schoolchildren to investigate the effects of urban noise on blood pressure. In the first phase of investigation acoustic measurements were performed on 115 streets of the central municipality “Stari grad” as a typical urban environment. Blood pressure measurements were performed using mercury sphygmomanometer in those subjects who did not have a diagnosed hypertension and were not under antihypertensive therapy. Among adults living in the streets with equivalent noise level (Leq) exceeding 45 dB (A) there was a significantly higher number of people with hypertension compared to areas with $Leq \leq 45$ dB (A) (23.6% vs. 17.5%). After statistical adjustments according to family history of hypertension, age, body mass index (BMI), smoking habits, physical activity and alcohol consumption among males, we found 58% increased odds for obtaining hypertension if they lived in noisy environments for more than 10 years (OR = 1.58; 95 CI = 1.03-2.42; $p = 0.038$). In females noise exposure and hypertension were not significantly related. In pre – school children aged 3 – 7 and living in areas with night $Leq > 45$ dB (A) and attending kindergartens in the streets with daytime $Leq > 60$ dB (A) the prevalence of hypertensive values of blood pressure was higher compared to children from quiet streets (5,7 % vs. 1,5 %; $p = 0,054$). Systolic blood pressure was significantly higher (5 mmHg on average) in children from noisy streets and kindergartens compared to children from quiet environments ($p < 0,01$). Multiple regression after adjustments according to age, sex, BMI percentile-for-age, family history of hypertension, and socioeconomic status revealed a significant positive correlation between the exposure to urban noise and systolic blood pressure ($p = 0,009$). In schoolchildren aged 7 – 11 and attending schools in streets with public transport we found a higher systolic blood pressure (1.3 mmHg on average) compared to children from schools without public transport, after adjustments according to age, sex, BMI, family history of hypertension, living conditions and health related behavioral habits ($p < 0.05$).

Key words: community noise; blood pressure; hypertension, children, adults.

Sažetak

Beogradski tim za biološke efekte buke koji čine stručnjaci iz oblasti higijene i kardiologije sproveo je populacione studije u Beogradu na uzorcima od 2503 odrasle osobe, 328 predškolske dece i 1113 školske dece o uticaju komunalne buke na krvni pritisak. Opština Stari Grad kao tipično gradska sredina poslužila je kao područje na kojem su u prvoj fazi istraživanja sprovedena akustička merenja u 115 ulica. Merenja krvnog pritiska obavljana su živim sfingmomanometrom kod onih ispitanika kod kojih nije dijagnostikovana hipertenzija i ne uzimaju terapiju. Kod odraslog stanovništva koje živi u ulicama sa ekvivalentnim nivoom noćne buke iznad 45 dB (A) bilo je značajno više ispitanika sa hipertenzijom u odnosu na sredine sa noćnom bukom ≤ 45 dB (A) (23.6% vs. 17.5%). Posle statističkog prilagođavanja u odnosu na porodičnu istoriju hipertenzije, dob, BMI, pušačke navike, fizičku aktivnost i konzumiranje alkohola, za muškarce je utvrđena za 58% veća šansa da dobiju hipertenziju ukoliko žive u bučnoj sredini duže od 10 godina (OR = 1.58; 95 CI = 1.03-2.42; $p = 0.038$), dok kod žena uticaj buke na pojavu hipertenzije nije značajan. Kod predškolske dece uzrasta 3-7 godina koja žive u sredini sa noćnom bukom $Leq > 45$ dB (A) i koja idu u obdaništa u ulicama sa dnevnim nivoom buke $Leq > 60$ dB (A) prevalencija hipertenzivnih vrednosti krvnog pritiska bila je viša nego kod dece iz tih ulica (5,7 vs. 1,5; $p = 0,054$). Sistolni pritisak bio značajno viši (5 mmHg u proseku) kod dece iz bučnih ulica i obdaništa u poređenju sa decom iz tih obe sredine ($p < 0,01$). Multipna regresiona analiza posle prilagođavanja u odnosu na dob, pol, percentil BMI u odnosu na dob, porodičnu istoriju hipertenzije i socioekonomski status pokazala je značajnu pozitivnu korelaciju između izlaganja dece komunalnoj buci i sistolnog pritiska ($p = 0,009$). Kod školske dece uzrasta 7-11 godina nađeno je da ukoliko su njihove škole locirane u ulici sa javnim saobraćajem sistolni pritisak je viši za 1.3 mmHg u odnosu na decu iz škola bez javnog saobraćaja, posle prilagođavanja u odnosu na dob, pol, BMI, porodičnu istoriju hipertenzije, uslove stanovanja i zdravstveno značajne navike ($p < 0.05$).

Ključne reči: komunalna buka, krvni pritisak, hipertenzija, deca, odrasli

INTRODUCTION

Urban noise is an emerging environmental problem both in developed and developing countries. More than 50% of the European population is annoyed by unacceptable daytime equivalent noise levels (L_{eq}) exceeding 55 dB while about one third of the population complains of sleep disorders due to exposure to night time L_{eq} exceeding 45 dB. (1) Road-traffic noise exposure is also an ever – increasing environmental problem in Serbian towns, especially in Belgrade, where daytime and nighttime noise limits are regularly exceeded by 10 – 20 dB. (2)

Hypertension is one of the major risk factors for early death in urban populations due to its association with the incidence of stroke, myocardial infarction, heart failure and end – stage renal disease. (3) The link between urban noise and hypertension has been intensively studied in the past three decades. A recent meta – analysis based on 24 cross – sectional studies on the association between road traffic noise and the prevalence of hypertension showed an odds ratio (OR) of 1.07 (95% confidence interval (CI) = 1.02–1.12, $P < 0.05$) per 10 dB increase of the 16-h day – time average road traffic noise level (L_{Aeq16h}) in the range of <50 to >75 dB. (4) Pathophysiological concept explaining the relationship between noise and hypertension is based on a general stress – reaction model. (5-6) Noise activates the hypothalamic – pituitary – adrenal axis and sympathetic nervous system and stimulates reticular formation with a consequent increase in the circulatory catecholamines and cortisol, which are of substantial importance for blood pressure (BP) regulation. (7)

The research of the Belgrade Team of Biological Effects of Noise (BETBEN) from the Faculty of Medicine University of Belgrade over the past decade has focused on two main scientific problems that were not sufficiently studied in previous investigations: nighttime noise in residential areas and noise around schools and kindergartens and BP of adults and children.

The World Health Organization has recognized nighttime noise as an important stressor related to diseases with the mediating effect of sleep deprivation. (8) However, commonly used daytime noise measurements in residential areas in the investigations on the relationship between noise and hypertension may be the source of exposure bias, because people, and especially children, usually spend most of their daytime hours out of home. (9) It may be assumed that nighttime noise measurements would alleviate the possible bias problem. Beside studies on adults, of special scientific relevance are investigations on children's BP and noise exposure due to small body of evidence and rather conflicting results from previous studies. There are reports both on the positive correlation between noise exposure and children's BP (10-11) and on the negative association. (12)

This is the review of the studies performed by BETBEN in Belgrade on the effects of road traffic noise on the BP among adults and children. (13-16)

The tested null hypotheses in our studies were: 1. Night-time noise in residential areas is not related to changes in BP among urban adult population and children; 2. There is no association between daytime road traffic noise around schools and kindergartens and BP among children.

The aims of our studies were: 1. To compare the prevalence of hypertension between the adult population living in residential areas with nighttime L_{eq} over and equal/below the adopted outdoor nighttime noise limit of 45 dB; 2. To investigate the effects of road traffic noise around kindergartens and nighttime noise around residences on BP levels of pre-school children; 3. To explore the effects of road traffic noise around schools and nighttime noise around residences on BP levels of schoolchildren. 4. To investigate the relationship between the presence of public transport as noise indicator and children's BP.

METHODS

Study samples

Adults

A cross – sectional study was performed on a sample of the adult population in a downtown Belgrade municipality. The estimated adult population of this municipality, according to the census data, was about 60.000. To obtain a 10% randomized sample of 6000 people, we used a step method in interviewing all adult residents of every tenth flat in all the streets. The appropriate numbers of questionnaires were delivered to post boxes inside the buildings according to the list of dwellers. The response rate was 52.8%, or 3169 completed questionnaires. The inclusion criteria for selecting the final subsample of residents were the period of residence longer than 10 years and a bedroom overlooking the street. The exclusion criteria included a high level of noise annoyance at work and the presence of diseases that might influence the occurrence of hypertension. Using these criteria, the sample was further reduced to 2,803 residents, 1,095 men and 1,708 women. The subjects who reported taking antihypertensive drugs were classified into a group with hypertension ($n=318$, 139 men and 179 women). Subjects who denied having medically confirmed hypertension or taking antihypertensive drugs ($n=2,485$) were contacted by phone and invited for BP measurement. The response rate was 87.9% ($n=2,185$, 856 men and 1,329 women). The final sample for investigation thus included a total of 2,503 subjects (995 men with an average age of 42,18 years [range 18–96 years] and 1,508 women with an average age of 40,17 years [range 18–91 years]).

Pre-school children

A cross – sectional study was performed on children aged 3 – 7 residing in a downtown Belgrade municipality, who attended 10 public kindergartens. Parents took the children to the kindergartens between 6 a.m. and 8 a.m. and brought them back home between 3 p.m. and 6 p.m. Parents were informed about the study and interviewed to obtain their approval for the examination of their children. The inclusion criteria for the sample were three or more years living on the present address and orientation of a child's bedroom towards the streets. The exclusion criterion for the sample was the presence of chronic diseases affecting arterial BP (diabetes mellitus and/or renal diseases). Out of 710 interviewed parents, 446 (62.8%) returned the questionnaires with the approval for examination. After applying the inclusion and exclusion criteria [living on the present address for less than 3 years ($n=21$); bedroom not oriented towards the street ($n=95$); diabetes mellitus ($n=1$); renal diseases ($n=1$)] the final sample consisted of 328 children (174 boys and 154 girls). The study sample was divided into four subsamples of children according to noise levels in the environment of residences and kindergartens. The environment of residence was regarded noisy if Leq exceeded 45 dB (A) during night (10 p.m. to 6 a.m.), and quiet if the Leq was ≤ 45 dB (A). The average Leq of noisy and quiet residences were 55.5 ± 6.7 dB (A) and 41.8 ± 3.0 dB (A), respectively. The environment of kindergarten was regarded noisy if daily Leq exceeded 60 dB (A), and quiet if Leq was ≤ 60 dB (A). The average Leq of the noisy and quiet kindergartens were 66.9 ± 5.3 dB (A) and 55.7 ± 2.8 dB (A), respectively. The four subsamples were created by applying the following acoustical characteristics of children's residences and kindergartens: 1. Quiet residence and quiet kindergarten ($n=60$; 29 boys and 31 girls); 2. Quiet residence and noisy kindergarten ($n=75$; 39 boys and 36 girls); 3. Noisy residence and quiet kindergarten ($n=62$; 37 boys and 25 girls), and 4. Noisy residence and noisy kindergarten ($n=131$; 69 boys and 62 girls).

Schoolchildren

A cross – sectional study was conducted in the municipality Stari grad, located in the center of Belgrade. This municipality is an administrative and residential area with road traffic as the principal source of noise. In total, eight public primary schools are located in this municipality. Investigators contacted children aged 7 – 11 (1st to 4th grade) and their parents through school boards. In the pilot study (15) the sample included 391 children (186 boys, 205 girls). Of 2000 interviewed parents in the final investigation (16), 1150 (57.5%) returned the questionnaires with the signed approval for examination of their children. Children gave their written consent for participating in this study. Ethics Committee of the Faculty of Medicine in Belgrade approved the study. The only exclusion criterion was the presence of chronic diseases affecting arterial BP (diabetes mel-

litus, heart or kidney diseases). Apart from pupils with diabetes ($n = 3$) and those absent from school on the day of examination ($n = 34$), the final sample consisted of 1113 children (533 boys and 580 girls).

Noise Measurements

Noise levels were measured in all 115 streets of the central Belgrade municipality “Stari grad”, as well as in front of 10 public kindergartens and eight elementary schools.

Hand – Held noise level analyzer type 2250 “Brüel and Kjær” was used, according to recommendations of International Standard Organization for the measurement of community noise (17). Noise levels were measured in the middle of the street. Noise was measured in two intervals during the day (between 10 a.m. and noon, and between 2 p.m. and 4 p.m.), in one evening interval (between 6 p.m. and 8 p.m.), and in two night intervals (between 10 p.m. and 12 p.m., and between midnight and 2 a.m.) In front of each kindergarten noise measurements were performed in two daily periods (9 a.m.–10.30 a.m. and 1.30 p.m.–3 p.m.). Noise levels around schools were measured on week days during lessons in two morning intervals (between 9 a.m. and 11 a.m., and between noon and 2 p.m.) and one afternoon interval (between 3 p.m. and 5 p.m.). The instrument was positioned on the pavement near the road; the time interval of each measurement was 15 min; the speed of sampling was 10/sec, with 9000 samples collected per measurement. Noise measurements were performed on several week days for each school; the measurements took place a few weeks after the examination of children in order to avoid researcher bias related to awareness of noise levels and traffic density.

A composite daytime equivalent noise level (Leq) was calculated for each kindergarten and school; a composite daytime and night time Leq levels were calculated for each street from the obtained emission noise values.

Blood Pressure Measurement

Adults

Participants were asked to avoid drinking coffee or smoking for half an hour before physical examination. A cardiologist took the BP measurements with a Fazzini mercury sphygmomanometer (cuff sizes 50–60 cm; width 14–17 cm; Fazzini, Italy). This instrument complies with the decision of Annex VI of the European Council Directive 93/42/EEC concerning medical devices. The measurements were performed on a week day in an outpatient department, between noon and 2 p.m., after a short rest of about 5 min. The subject was in a sitting position, and the mean value was determined from two measurements performed on each arm. If the difference between measurements exceeded 5 mmHg, a third measurement was performed on the same arm.

Hypertension was diagnosed according to the criteria established by the Seventh Report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (systolic pressure ≥ 140 mmHg and/or diastolic pressure ≥ 90 mmHg) (18). Ambulatory BP monitoring was applied in 175 participants (64 men and 111 women) with borderline BP levels and fluctuation from normal to hypertensive values. BP was measured every 30 min over a 24-h period including both waking and sleeping hours on weekdays. The criteria for hypertension based on the ambulatory BP measurements were a mean systolic pressure > 135 mmHg and/or a mean diastolic pressure > 85 mmHg (18). The proportion of subjects in whom hypertension was diagnosed through the BP measuring procedure was 7.5% ($n=163$), out of which there were 79 men (9.2%) and 84 women (6.3%). Within this group, 98 cases of hypertension (52 men and 46 women) were diagnosed by BP measurement with a sphygmomanometer, and 65 cases of hypertension (27 men and 38 women) were diagnosed by additional ambulatory BP monitoring. In the whole investigated sample the total proportion of subjects with hypertension was 19.2% ($n=481$) out of which there were 218 men (21.9%) and 263 women (17.4%).

Children

Children's BP was measured using mercury sphygmomanometer "Fazzini", Italy in a kindergarten or a school. Cuff sizes of 7.5×19.5 cm or 11×27 cm were used according to arm measurement criteria (19). This instrument complies with the decision according to Annex VI of the Council Directive 93/42/EEC concerning medical devices. 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 measured BP levels exceeded 5 mm Hg, the third measurement was performed and mean values of systolic and diastolic pressures were calculated. Heart rate was measured by radial artery palpitation for 1 min. The measurements were performed by one of two researchers – medical doctors trained according to the study protocol. Children were not allowed to talk during the measurement session. Hypertension was diagnosed if systolic and/or diastolic pressure were equal or exceeding 95th percentile of values, according to body height, sex, and age (20).

QUESTIONNAIRES

Adults

The questionnaire was anonymous and it consisted of two segments. The first part comprised general socio – demographic data: age, sex, education, employment, period of residence, daily time spent in the apartment, apartment size, number of dwellers, and orientation of the bedroom(s) (toward the street or not).

The second segment consisted of questions on antihypertensive therapy and possible confounding factors, such as family history of hypertension, body weight and height, smoking habits, physical activity, and alcohol consumption, graded on a six – point scale (0: never; 1: several times a year; 2: 1 – 3 times a month; 3: 1 – 3 times a week; 4: 4 – 6 times a week; and 5: every day). There were also questions concerning medically confirmed diseases related to hypertension: diabetes mellitus, renal diseases, aortal coarctation, Cushing's Syndrome, hyperthyreosis, pheochromocytoma, primary aldosteronism, acromegaly and hyperparathyroidism.

Children

The questionnaire consisted of two segments. The first part comprised general socio-demographic data: child's age, sex, birth by order, parental education (coded as: 1—elementary school; 2—secondary school; 3—college; 4—faculty), parental employment, marital status, monthly income (coded as: 1—insufficient; 2—sufficient; 3—more than sufficient), apartment size, number of dwellers, floor. The second part of the questionnaire consisted of questions on family history of hypertension, child's birth weight and diseases related to arterial hypertension (diabetes mellitus, renal diseases).

STATISTICAL ANALYSIS

Data are presented as the means $\pm$ SD for numeric variables, or as percentages (relative numbers) for categorical variables. Differences between groups in parametric data were compared using Student's *t*-test and one – way ANOVA [followed by Least Significant Difference Test (LSD) post hoc analysis]. Mann Whitney U-test and Chi-square test were used for nonparametric data. Pearson correlation analysis was performed to test the association between variables from the questionnaire and children's BP and heart rate. Based on the results of univariate analyses, variables significantly related to BP and heart rate were included in a multiple linear regression model. Univariate logistic regression was performed to calculate OR for arterial hypertension in relation to relevant independent variables. Multiple logistic regression was used to calculate adjusted OR for arterial hypertension in relation to noise exposure. A probability level of less than 0.05 was accepted as significant. We used SPSS 15.0 for Windows software (SPSS Inc. 1989-2006).

RESULTS

Main findings of the performed studies in Belgrade are presented in Table 1.

The prevalence of hypertension among male adults living in residential areas with a higher nighttime noise level

Table 1. Main findings of the studies in Belgrade on the relationship between noise exposure and blood pressure of the population

Reference	Design	Sample size	Exposure assessment method	Blood pressure measurement	Main finding	Effect Size
Belojevic et al. (13)	Cross-sectional	2503 adults (995 male & 1508 female) Belgrade	L night 8h > 45 dB (A) vs. ≤ 45 dB (A)	Diagnosed hypertension & Sphygmomanometer measurement	Higher prevalence of and odds for hypertension among males exposed to L night 8h > 45 dB (A) vs. ≤ 45 dB (A)	OR (95% CI) 1.58 (1.03 -2.42)
Belojevic et al. (14)	Cross-sectional	328 preschool children (age 3-7) 174 boys, 154 girls, Belgrade	Lnight, ≤ 45 dB (A) vs. > 45 dB (A); kindergarten: Lday, ≤ 60 dB (A) vs. > 60 dB (A)	Sphygmomanometer measurement	More children with hypertensive values of BP and higher systolic BP from noisy residences and kindergartens vs. quiet residences and kindergartens	5.70% vs. 1.48%; p = 0.054; 5 mm Hg mean difference (P < 0.01)
Belojevic et al. (15)	Cross-sectional	391 schoolchildren (age 7-11) 186 boys, 205 girls, Belgrade	Lnight, ≤ 45 dB (A) vs. > 45 dB (A); School: Lday, ≤ 60 dB (A) vs. > 60 dB (A)	Sphygmomanometer measurement	Higher systolic BP among children from noisy residences and schools vs. quiet residences and schools	4 mm Hg mean difference (P < 0.01)
Paunovic et al. (16)	Cross-sectional	1113 schoolchildren (533 boys; 580 girls)		Sphygmomanometer measurement	Higher systolic BP among children from residences and schools from the streets with public transport vs. no public transport	2 mm Hg mean difference (P < 0.05)

was higher compared to the population from less noisy areas (23.6% vs. 17.5%). Odds ratio adjusted for age, body mass index, physical activity, subjective noise sensitivity, noise annoyance, family history of hypertension and alcohol consumption pointed to 58% higher probability of obtaining hypertension if exposed to noise. There was no significant effect of noise on BP of females.

Systolic pressure was significantly higher (5 mm Hg on average) among pre-school children from noisy residences and kindergartens compared to children from both quiet environments ($p=0.001$). Diastolic pressure and mean arterial pressure were similar between the groups. The prevalence of children with hypertensive values of BP was 3.96% (13 children, including 8 boys and 5 girls), with higher prevalence in children from noisy residences (5.70%), compared to children from quiet residences (1.48%). The difference was borderline significant ($\chi^2=3.71$; $p=0.054$). To determine the relationship between noise exposure and studied cardiovascular parameters allowing for age, parental education, family history of hypertension and family income, multiple linear regression analysis was performed. The correlation was positive and significant ($B = 1.056$ (95% CI= 0.269-1.843) ($P = 0.009$)).

In the pilot study on school children (15) the systolic BP among children from noisy residences and schools was higher compared to children from quiet residences and schools. The multiple linear regression adjusted for age, parental education, family history of hypertension and family income showed that systolic pressure was positively and significantly related to noise exposure ($B = 3.413$ (95% CI= 1.903-4.923) ($P < 0.001$)).

The final study on schoolchildren showed that children attending schools with public transport running nearby had by 1.3 mmHg higher systolic BP compared to children from schools without public transport. (16) This effect was independent from children's age, gender, BMI, family history of hypertension, physical activity and eating habits.

DISCUSSION

Our investigations show that nighttime road – traffic noise is significantly related to hypertension in the adult male urban population. We also show that systolic pressure is higher among children exposed to noise at home and at kindergartens or schools, compared to children from two quiet environments. There is a possible positive association between the presence of public transport near schools and systolic BP in schoolchildren.

So far, few studies have focused on the influence of nighttime noise. One of these is a study conducted in the city of Erfurt in Germany. It was designed as a longitudinal 5 – year prospective study investigating health benefits of lowering traffic noise levels by 10 dB(A) in the residential area. (21) The results showed that the recovery of the patients with arterial hypertension was more frequent than in the control group where no such measures were undertaken. Only one German survey distinguished the effects of nighttime vs. daytime noise exposure, showing slightly higher relative risk for hypertension in association with night noise (22). That study revealed significant risk for the occurrence of hypertension among men exposed to nighttime noise

levels exceeding 55 dB(A), independent from other possible confounders, including age, body mass index, physical activity or family history of hypertension.

The presented results on noise exposure and children's BP are partially in accordance with the results from Bratislava study on preschool children (11) and with the Inn Valley study (10). In the Bratislava study significantly higher systolic and diastolic BP readings were reported in children aged 3 – 7, from homes and/or kindergartens exposed to traffic noise of $Leq_{24h}N_{60}$ dB compared to those from less exposed areas ($Leq_{24h} \leq 60$ dB). The findings of the London study (12) were mainly opposite to our results, showing significant negative association between daytime road – traffic noise at schools and children's systolic pressure. However, the effect of road – traffic noise at home was not investigated. Daytime and night time aircraft noises at home were significantly and positively associated with BP.

The clinical significance of the observed 2-5 mm Hg difference in the mean systolic pressure level between children exposed to higher and lower noise levels is

difficult to determine. It is also challenging to predict whether and to what extent slight increases in children's BP can cause possible health risks in later life, although there is evidence that elevated BP values in childhood might be related to hypertension in young adults (23).

CONCLUSION

The investigations of the BETBEN over the past decade show that road traffic noise might be regarded as a significant risk factor for hypertension in adult urban population and an important stressor that might elevate systolic BP in children.

NAPOMENA

Rad je usmeno izložen na mini simpozijumu Higijensko-ekološki činioci i zdravlje na 43. simpozijumu Strem-ljenja i novine u medicini, Medicinski fakultet u Beogradu, 12.12.2014. godine.

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