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Original Article

Noise exposure at school and blood pressure in adolescents

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Abstract

Background The increasing prevalence of primary hypertension has motivated researchers to identify influencing factors, one of which is noise. There have been few studies on a relationships between noise exposure and blood pressure in children, and none have dealt exclusively with adolescents.

Objective To assess for an association between noise exposure at school and blood pressure in adolescents.

Methods To identify noisy and quiet schools, the mean noise levels of 192 senior high schools in Medan were measured using sound level meters. One noisy school and one quiet school were randomly selected for inclusion (mean noise levels of 68.2 and 53.8 dB, respectively). Students from both schools underwent blood pressure measurements by mercury sphygmomanometer. Their body weights and heights were obtained for body mass index calculations. Subjects filled questionnaires and their parents were interviewed regarding history of illnesses.

Results Of the 271 adolescents recruited, 136 (50.2%) were from the noisy school. Adolescents from the noisy school had higher mean systolic and diastolic blood pressures [121.6 (SD 13.87) mmHg and 71.1 (SD 8.15) mmHg, respectively], than those from the quiet school [111.8 (SD 12.61) mmHg and 63.8 (SD 8.05) mmHg, respectively]. After adjusting for other factors, noise had a significant, moderate, positive association with systolic and diastolic blood pressures [β= 0.452; B = 6.21 (95% CI 3.86-8.55) mmHg; and β= 0.473; B = 4.18 (95% CI 2.41 to 5.94) mmHg, respectively].

Conclusion Adolescents from a noisy school have a greater risk of higher systolic and diastolic blood pressures than those from a quiet school. **[Paediatr Indones. 2016;56:331-8. doi: 10.14238/pi56.4.2016.331-8]**.

Keywords: *blood pressure; noise; adolescent*

Hypertension is a common health problem, with a worldwide prevalence of 40% in 2008. If hypertension remains undetected and untreated, it may lead to fatal complications, such as atherosclerosis, myocardial infarction, stroke, encephalopathy, retinopathy, as well as renal and heart failure.[1] The Bogalusa Heart Study reported that elevated blood pressure (BP) in childhood and adolescence could persist and progress to adult hypertension. Adolescent BP had a stronger correlation to BP in adulthood than did childhood BP.[2]

Hypertension among adolescents has increased in prevalence.[3] Hypertension might be associated with the growing incidence of overweight and obesity,[4] as well as exposure to certain environmental factors that were minimized in the past, such as air pollution

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and noise.[5] Noise has been reported to elevate BP by its excitatory effect on the autonomic nervous and hormonal systems. Noise causes excitation along the auditory pathway that continues not only to the auditory cortex, but also to the hypothalamus via a separate paucisynaptic pathway from the geniculate body of the thalamus, a part of auditory pathway, to the amygdala. Stimulating the amygdala excites the nearby hypothalamus, resulting in two main processes: the activation of the sympathetic nervous system which in turn stimulates the adrenal medulla to produce catecholamines, and the stimulation of the adrenal cortex by the anterior pituitary to produce cortisol.[6] Previous studies have reported an association between noise and blood pressure in both preschool-aged,[7] and school-aged children.[8] However, two other studies which confirmed this association in adolescents, merged their data with other age groups (adults[9] and younger children[10]). The aim of this study was to assess for an association between noise exposure at school and blood pressure in adolescents.

Methods

Before this study began, a preliminary survey was performed from September to October 2012 to measure the mean noise level at 192 senior high schools listed in the Medan Education Agency database. Noise was measured using a calibrated *Tenmars™ TM-102* digital sound level meter, which was able to detect noise ranging from 30 to 130 dB, with an accuracy of ±1.5 dB and a precision of 0.1 dB. Noise was recorded in decibels (dB). Noise measurement was performed twice for every school at two-hour intervals (8 to 9 AM and 10 to 11 AM) by recording the numbers displayed on the sound level meter's screen every two seconds for five minutes at every measurement spot. The measurement spots for all schools were at the inner front part of the school fence and continued every 5 meters inside the school, all the way to the back of the building. Mean noise levels were calculated for all schools.

Schools were divided into two categories, based on their noise level. Schools with mean noise level of more than 55 dB were considered to be noisy schools, whereas those with mean noise level of 55 dB or less were considered to be quiet schools (in accordance with the *Ministerial Decree for the Environment* No.KEP.48/MENLH/11/1996 on noise level standards). The results of this survey indicated that 105 of 192 high schools in Medan (54.6%) were in the noisy school category, while the remaining 87 schools were in the quiet school category. One school from each category was randomly selected for the purposes of this study. This cross-sectional study was conducted in March 2014. Due to the long period between the preliminary survey and the study, we remeasured the mean noise level of the selected schools at the time of the study to confirm that the selected schools remain representative for their noise category.

The inclusion criteria were adolescents aged 14 to 17 years, with normal pubertal status and had attended the selected school for at least one year. The exclusion criteria were those with obesity, hearing impairment, renal or cardiovascular disease, or history of consuming BP-influencing drugs or caffeine during the 24 hours prior to BP measurement. This study was approved by the Health Research Ethics Committee of the University of Sumatera Utara.

Information about the study was provided to parents and subjects prior to data collection. Subjects filled structured questionnaires, which included questions on age, sex, ethnicity, other personal data, cell phone number, history of hypertension or other chronic diseases (renal/cardiovascular/endocrine) and history of consuming BP-influencing drugs and caffeine during the prior 24 hours. Subjects' blood pressures were measured using a Nova Riester mercury sphygmomanometer and a Littmann Classic II pediatric stethoscope. A cuff size of 13 x 30 cm was used, as recommended by the *National High Blood Pressure Education Program* (NHBPEP).[11] Three measurements at five-minute intervals were performed on all subjects, after a 15-minute rest in a sitting position, with the subject's right arm at heart level. The first Korotkoff sound was determined to be systolic blood pressure (SBP) and the fifth Korotkoff sound to be diastolic blood pressure (DBP). Mean values of SBP and DBP were calculated. Revised BP tables assigned by NHBPEP (2004) were used to determine BP percentiles and classification.[11]

Subjects' body weights and heights were measured using a calibrated Camry scale with a precision of 0.1 kg, and a 2-meter microtoise with a precision of 0.5 cm, respectively. Body mass index (BMI) was calculated using the Quatelet index (weight in kg divided by quadratic height in m^2)[12] and plotted against BMI-for-age charts developed by the *Centers for Disease Control and Prevention,*[13] to determine nutritional status. Subjects underwent physical examinations to rule out clinical abnormalities. Subjects' pubertal status was determined with a staging system formulated by Marshall and Tanner.[14] To rule out hearing impairments, audiometric screening was performed on subjects. Hearing impairment was defined as mean air conduction threshold exceeding 25 dB in one or both ears. Family history of hypertension and hypercholesterolemia was assessed by parental phone interviews as well as prior hypertension diagnosed by a doctor and total cholesterol levels exceeding 200 mg/dL on venous or capillary blood test.

The minimum required sample size was calculated for 90% power and 5% level of significance. We used a standard deviation of 13, based on a previous study.[9] With an assumption of 5 mmHg to be a clinically important difference, a total of 116 students was required from each school category. Data were processed and analyzed with *SPSS version 16.0.* Unpaired T-test, Pearson's correlation, Spearman's correlation, and ANOVA tests were used for bivariate analysis of variables in relation to BP. The influence of noise on BP was examined by multiple linear regression tests. Blood pressure was adjusted for the effects of gender, height, ethnicity, BMI, as well as family history of hypertension and hypercholesterolemia. Results were considered to be statistically significant for P values below 0.05, with 95% confidence intervals (CI).

Results

For our study, we selected one noisy school and one quiet school in Medan.. Mean noise levels of the two selected schools in the first and second measurements, respectively, were 70.4 (SD 6.57) dB and 68.2 (SD 4.38) dB for noisy school, whereas for quiet school, 52.2 (SD 3.13) dB and 53.8 (SD 3.34) dB. Of 513 students screened from these schools, 493 returned the questionnaires with parents' written approval for study participation. A total of 222 students were excluded due to obesity (30), hearing impairment (71),

Table 1. Characteristics of subjects

Characteristics	Overall (n=271)	Noisy school (n= 136)	Quiet school (n= 135)
Mean age (SD), years	16.6 (0.68)	16.6 (0.63)	16.5 (0.72)
Gender, n (%)			
Male	106 (39.1)	54 (39.7)	52 (38.5)
Female	165 (60.9)	82 (60.3)	83 (61.5)
Ethnicity, n (%)			
Chinese	130 (48.0)	130 (95.6)	0 (0)
Batak	113 (41.7)	3 (2.2)	110 (81.5)
Miscellaneous*	28 (10.3)	3 (2.2)	25 (18.5)
Mean body weight (SD), kg	53.7 (9.01)	55.0 (9.67)	52.4 (8.13)
Mean body height (SD), cm	160.3 (8.47)	162.3 (7.46)	158.2 (8.94)
Mean BMI (SD), kg/m^2	20.9 (2.82)	20.9 (3.04)	20.9 (2.59)
Nutritional status, n (%)			
Underweight	17 (6.3)	9 (6.6)	8 (5.9)
Normoweight	221 (81.5)	109 (80.1)	112 (83.0)
Overweight	33 (12.2)	18 (13.2)	15 (11.1)
Mean air conduction threshold of right ear (SD), dB	18.8 (3.65)	18.9 (3.63)	18.7 (3.69)
Mean air conduction threshold of left ear (SD), dB	18.3 (3.65)	18.4 (3.93)	18.2 (3.35)
Mean SBP (SD), mmHg	115.6 (13.76)	121.6 (13.9)	1 11.8 (12.6)
Mean DBP (SD), mmHg	67.5 (8.85)	71.1 (8.15)	63.9 (8.05)
BP classification, n (%)			
Normotension	185 (68.3)	76 (55.9)	109 (80.7)
Pre-hypertension	42 (15.5)	24 (17.6)	18 (13.3)
Hypertension grade I	35 (12.9)	28 (20.6)	7 (5.2)
Hypertension grade II	9 (3.3)	8 (5.9)	1 (0.7)
Mean noise level, dB	56.7 (6.57)	68.2 (4.38)	53.8 (3.34)

* Miscellaneous: Malay, Minangkabau, Javanese, Acehnese, Arabian, and Pakistani; SBP=systolic blood pressure; DBP=diastolic blood pressure

cardiovascular (2) and renal disease (1), consumption of caffeine or BP-influencing drugs in the 24 hours prior to BP measurement (63), and incomplete data (55). Hence, 271 subjects joined the study (136 subjects from a noisy school and 135 subjects from a quiet school).

Subjects' characteristics are shown in **Table 1**. Their mean age was 16.6 years and there were more girls (60.9%) than boys. in terms of subjects' ethnicities, the noisy school students were predominantly of Chinese descent, while the quiet school students were predominantly of Batak descent. There were slightly more overweight and taller subjects from the noisy school than from the quiet school, although the groups had similar mean BMIs (20.9 kg/m^2). Audiometric screening revealed that mean air conduction thresholds of right and left ears were similar between the two groups (about 18 dB). Subjects from the noisy school had higher SBP and DBP, and a larger proportion of

Table 2. Bivariate analysis of SBP and DBP in relation to age, sex, and height

Variable	P values	
	SBP	DBP
Age*	0.462	0.440
Sex**	0.001	0.258
Height***	0.001	0.001

* Correlation coefficient for SBP: 0.006; DBP: 0.009
** Mean difference (95% CI) for SBP: 11.9 (8.9-14.9); DBP: 1.3 (-0.9-3.4)
*** Correlation coefficient for SBP: 0.396; DBP: 0.188

Table 3. Bivariate analysis of SBP and DBP in relation to noise, ethnicity, BMI, as well as family history of hypertension and hypercholesterolemia

Variables	SBP			DBP		
	Mean mmHg (SD)	Mean difference (95%CI)	P value	Mean mmHg (SD)	Mean difference (95%CI)	P value
Noise category						
Noisy school	121.6 (13.87)	9.8 (6.5 to 12.9)	0.001	71.1 (8.15)	7.2 (5.2 to 9.1)	0.001
Quiet school	111.8 (12.61)			63.8 (8.05)		
Ethnicity						
Chinese	121.1 (13.85)	10.4 (6.7 to 14.2)*	0.003	70.7 (8.12)	6.1 (4.1 to 8.2)*	0.001
Batak	110.7 (10.99)	0.6 (-6.3 to 7.6)		64.5 (8.37)	-0.1 (-3.4 to 3.5)^	
Miscellaneous	110.1 (14.01)	11.0 (3.9 to 18.2)≠		64.6 (9.11)	6.1 (2.7 to 9.5)≠	
BMI	NA#	NA#	0.001€	NA#	NA#	0.004€
Nutritional status						
Underweight	116.2 (12.22)	1.9 (-4.6 to 8.6)¶	0.001	69.2 (9.98)	2.4 (-1.9 to 6.8)¶	
Normoweight	114.2 (13.25)	-10.6 (-15.5 to -5.7)$		66.8 (8.45)	-4.1 (-7.8 to -0.9)$	
Overweight	124.8 (14.69)	-8.6 (-16.5 to -0.8)¥		70.9 (10.16)	-1.7 (-6.8 to 3.5)¥	
Family history of hypertension						
Positive	118.2 (14.29)	4.3 (0.9 to 7.6)	0.013	68.4 (9.6)	1.6 (-0.7 to 3.8)	0.206
Negative	113.9 (13.18)			66.8 (8.3)		
Family history of hypercholesterolemia						
Positive	118.0 (14.29)	4.3 (1.1 to 7.6)	0.011	68.5 (8.4)	1.9 (-0.2 to 3.9)	0.082
Negative	113.6 (13.04)			66.6 (9.1)		

* Chinese *vs.* Batak for SBP and DBP: P<0.001; ^ Batak vs. Misc. for SBP: P=0.486, for DBP: 0.495
≠ Chinese *vs.* Misc. for SBP and DBP: P<0.001
€ Correlation coefficient for SBP: 0.243; for DBP: 0.159
Not applicable; ¶ Underweight vs. Normoweight for SBP: P=0.279, for DBP: 0.135
$ Normoweight *vs.* Overweight for SBP: P<0.001, for DBP: 0.007
¥ Underweight *vs.* Overweight for SBP: P=0.016, for DBP: 0.262

hypertension and pre-hypertension than subjects from the quiet school.

The results of bivariate analysis of SBP and DBP are shown in **Tables 2** and **3**. All variables studied, except for age, were significantly associated with SBP, while four variables (height, noise, ethnicity, and BMI) were significantly associated with DBP. All variables with P values < 0.25 were included in the multivariate analysis. **Table 4** shows the effect of noise on SBP and DBP after adjusting for other factors with multiple linear regression analysis. Noise exposure at school was significantly, positively, and moderately associated with both SBP and DBP (β: 0.452 and 0.473, respectively). For every 14.4 (95% CI 10.67 to 18.13) dB increment of noise level (difference of mean noise level between the two selected schools from the second measurement), SBP and DBP increased as much as 6.21 (95%CI 3.86 to 8.55) mmHg and 4.18 (95%CI 2.41 to 5.94) mmHg, respectively.

Table 4. Multivariate analysis of noise in relation to SBP and DBP

BP	Adjusted B coefficient	95%CI for B	SE	P value
SBP*	6.21	3.86 to 8.55	0.52	0.001
DBP**	4.18	2.41 to 5.94	0.89	0.001

* After adjusting for gender, height, BMI, ethnicity, as well as family history of hypertension and hypercholesterolemia
**After adjusting for height, BMI, ethnicity, as well as family history of hypertension and hypercholesterolemia

Discussion

Our study showed that noise exposure at school was moderately associated with SBP and DBP. The results of this study are in accordance with three previous studies.[7,8,10] A Slovakian study was the first to observe an association between noise exposure and BP in children. Both SBP and DBP were about 4 to 5 mmHg higher in children from a noisy school compared to those from a quiet school, and 2 mmHg higher in children from noisy residence compared to those from a quiet residence.[7] A Serbian study reported that children from a noisy school had 2 mmHg higher SBP and DBP than those from a quiet school. After controlling for other factors, noise exposure at school had a statistically significant positive association with SBP and DBP.[8] *The German Environmental Survey IV* (GerES IV) demonstrated that students at noisy schools had SBP and DBP increases of as much as 1 mmHg and 0.6 mmHg, respectively, for every 10 dB increment of noise, after adjustment for other factors.[10]

Two other previous studies reported that noise exposure was significantly associated with SBP, but not DBP.[15,16] After adjustment for other factors, one study noted this association for both noise exposure at school and residence, [15] while the other study found this association only for noise exposure at school, not residence. [16] Furthermore, a study from southern Germany reported a significant association between noise exposure and the incidence of hypertension, with an odds ratio of 1.49. Unfortunately, their study results cannot be compared to ours because they used categorical data and their diagnosis of hypertension was based on adult criteria (JNC VII).[9]

In general, all previous studies and our study found that noise had stronger associations with SBP than with DBP. This potential noise effect may be caused by sympathetic nervous system activation and stress hormone secretion (adrenaline, noradrenaline and cortisol) which contribute to increased cardiac output and arteriolar resistance, thus, elevating the SBP as an adaptive response to the stressor. [17,18] In addition, noise-induced emotional stimuli activate skin receptors, lead to vasoconstriction, and, consequently, elevate the SBP. DBP is the minimal blood pressure during heart relaxation and is determined by intravascular volume, hydration status, and serum electrolyte level. The role of DBP is to ensure optimal perfusion to peripheral tissues. This theory may explain why DBP, unlike SBP, remains stable or only changes a little throughout daily activities.[19]

The degree of BP elevation varied across studies,[7-10,15,16] possibly due to differences in noise and

BP measurement methods, as well as identification and adjustment of other BP-influencing factors. The study from Southern Germany had the most accurate noise measurement technique. They used personal noise dosimeters to measure their subjects' noise exposure.[9] This device more accurately measures individual noise exposure because it is attached to the subject's attire, thus, measuring the noise perceived by the person wearing it. Unfortunately, this device can only be used by one person at a time. Hence, its impracticality and lack of availability deterred us from using it in our study.

Our study and five previous studies[7,8,10,15,16] used standard sound level meters, which accurately measure noise intensity, but do not relfect individual noise exposure. In addition to noise intensity, individual noise exposure is affected by the presence of barriers and/or distance from the noise source. In five previous studies, noise measurement was solely performed in front of school or residential buildings,[8,15,16] open room windows,[10] or by the roadside.[7] In our study, noise measurement was not only performed in front of the school buildings, but continued to the back of the building. Considering the facts that noise exposure at school is not always from road traffic and noise exposure is affected by distance and barriers, this effort was done with the hope of minimizing measurement bias. In terms of time, noise measurement was done only in the daytime, because three previous studies reported that residential noise at night did not significantly influence BP values.[7,8, 16]

In terms of BP measurement, three of six previous studies used an auscultation method by mercury sphygmomanometer with a cuff size adapted for age.[8,15,16] Two other studies used an automatic device,[9,10] one of which did not explain an adjustment of cuff size.[10] Another study used a Doppler ultrasound device.[7] In our study, BP measurement was performed on the subject in a sitting position with the right arm at heart level, by auscultation method using a mercury sphygmomanometer with a cuff size of 13 x30 cm (according to NHBPEP recommendations).[11]

Blood pressure is a dynamic value resulting from a complex interaction of many factors.[20,21] Therefore, in assessing the influence of noise on BP, proper identification and adjustment of these factors are necessary. Three studies adjusted for age, gender, anthropometry (BMI or BMI percentile), family history of hypertension, the presence of chronic disease, birth weight, and family background (family income, parental education level, house size, and number of floors). We did not include birth weight and family background in our analysis because those three studies found no significant associations between those factors and BP values.[8,15,16]

One previous study only controlled for age and height with no explanation about excluding children with chronic disease, as that might have affected BP values.[7] Another study did not analyze anthropometric parameters. Factors affecting BP considered in that study were only age and gender.[9] The GerES IV was the only study that took into account physical activity and hearing impairment. Factors analyzed in that study were age, gender, weight, height, physical activity, socioeconomic status, noise annoyance, and agglomeration level. Hearing tests were done before data analysis, although the type of hearing test was not specified.[10]

For our study, we attempted to scrupulously consider factors with potential to influence BP. All subjects with obesity, hearing impairment, renal and cardiovascular disease, as well as history of consuming BP-influencing drugs and caffeine for the 24 hours before BP measurement were excluded. Our study was the only one that included ethnicity and family history of hypercholesterolemia in the analysis. Physical activity was not assessed in our study, nor in the five previous studies.[7-9,15,16] Several other factors that were not considered in any studies were salt intake, emotional factors (fear or anxiety), serum cortisol ,and/or catecholamine levels.

Normal pubertal status was one of our inclusion criteria. Two previous studies examining adolescents did not take pubertal status into account in their inclusion criteria or data analysis.[9,10] Pubertal status should be considered in all studies assessing BP values in adolescents, as this is a stage during which fast growth and rapid change of body mass and BP occur.[19,22] As such, a cohort study had reported that the velocity of SBP elevation at puberty was faster than that at pre-puberty, at a rate of 3 to 6 times for boys and 2 to 4 times for girls.[23]

Our study had several limitations, similar to the previous studies. First, this was a cross-sectional study, therefore, a causal relationship between noise exposure and BP values cannot be determined, and it is unknown whether an effect of noise on blood pressure is temporal or permanent. Second, measurement bias of noise exposure might have occurred, since we did not use personal noise dosimeters. Third, we did not take into account several other factors affecting BP values, such as salt intake, physical activity, stress, and emotional factors, because of the difficulty in obtaining the data. Fourth, we did not check serum cortisol or catecholamine levels to confirm the pathophysiology of noise-induced BP elevation. However, our study has two major strengths. First, consideration for other factors affecting BP values was thoroughly done by restriction and multivariate analysis. Second, we focused exclusively on adolescents, while, to date, only two studies which included adolescents either merged the data with adults,[9] or younger children.[10]

Our findings show that noise exposure at school is associated with higher SBP and DBP in adolescents. To confirm these results, further research with a cohort method, larger sample size, using personal noise dosimeters, allowing additional analysis for salt intake, physical activity, emotional factors, serum cortisol, and catecholamine level is needed.

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Conflict of Interest

None declared.

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