12th ICBEN Congress on
Noise as a Public Health Problem

Cardiometabolic risks of exposure to different environmental noise sources in vulnerable population

Lubica Argalasova[1], Ludmila Sevcikova[1], Diana Vondrova[1], Zuzana Stefanikova[1], Jana Babjakova[1], Alexandra Filova[1], Martin Samohyl[1], Katarina Hirosova[1], Jana Jurkovicova[1]

[1] Comenius University in Bratislava, Institute of Hygiene, Bratislava, Slovakia (corresponding author)

Corresponding author's e-mail address: lubica.argalasova@fmed.uniba.sk

ABSTRACT

The recent advances in research have pointed out a possible relationship between traffic noise, type 2 diabetes, and obesity. The study aims to examine the association between exposure to environmental noise sources and markers of obesity (body mass index, BMI), WC (waist circumference), WHR (waist/hip ratio), and percentage of body fat) in the sample of university students in Slovakia. The sample comprised of 484 university students (mean age 22.9±2 years, 25.6% males); 188 living in the dormitory exposed to road traffic noise and 296 living in the control area, for more than 4 years. Students from the exposed group are more annoyed by road traffic, tramway and entertainment facilities noise. The bivariate analysis showed higher, but not significant levels of all obesity markers in the group exposed to traffic noise. The results were significant only for body fat percentage assessed by NIR method in the categorical analysis in men (OR=2.19; 95% CI 1.1-4.75, p=0.048), after adjustment for possible confounding factors. Future research is necessary in this new field to extend its inferences to the general population.

INTRODUCTION

The growing impact of exposure to environmental noise on health is one of the major health risks of the present time. This negative environmental factor is different from the other pollutants, the levels are increasing and it is constantly applied to the human, also during the time designated for relaxation, such as sleep [1, 2, 3].

Sleep disturbance by noise (especially from road traffic) is the most serious environmental burden of disease, representing 903,000 disability-adjusted life-years (DALYs) [4].

Road traffic noise has been found to be associated with cardiovascular diseases. Noise, as a stressor, is responsible for blood pressure and blood lipids increase, that can later manifest in chronic diseases (hypertension, coronary heart disease) [5,6,7,8,9]. As a result of meta analysis, a common risk curve is derived for the relationship between road traffic noise and the incidence of myocardial infarction (MI) [10].

Recent findings suggest that environmental, especially traffic noise may also affect the endocrine and metabolic system, for example inducing type 2 diabetes and central obesity.

Traffic noise can influence cardiovascular and metabolic functions through sleep disturbances and chronic stress [11, 12]. For example, short sleep duration is associated with a reduction of serum leptin and elevation of ghrelin, leading to an increased appetite. Furthermore, an activation of the Hypothalamic-Pituitary-Adrenal axis results in elevated levels of cortisol, which promotes central fat deposition and impaired glucose regulation [13]. Recently, some interesting epidemiological studies on large samples of respondents and meta analyses have been published and indicate associations between noise exposure and obesity and type 2 diabetes controlling for potential environmental and life style confounders [11, 12, 13, 14, 15].

AIM OF THE STUDY

The study aims to examine the association between exposure to environmental noise sources and markers of obesity (body mass index, BMI), WC (waist circumference), WHR (waist/hip ratio), body fat percentage and percentage of visceral fat) in the sample of university students in Slovakia.

METHODS

Road traffic noise exposure objectification

Equivalent noise levels were assessed for both the control and exposed groups in Slovakian capital Bratislava by hand-held sound level analyzer. All measurements were recorded according standard methods during the time intervals from 17.00-18.00 and from 20.00-21.00 in the exposed and at the same time in the control area. This time interval was chosen to record the afternoon traffic peak and to detect the time most annoying for students and for their activities (studying, watching TV, talking, relaxing, and falling asleep). Measurements were recorded during spring period at working days (Tuesday) two times on each site. Road traffic flow composition was assessed as well. The L_{den} was estimated from the Bratislava agglomeration strategic noise map (Figure 1) [16].

Sample

The sample comprised of 484 university students, 25.6% males and 74,4% females, mean age 22.9±2 years, 188 (38.8%) living in the dormitory exposed to road traffic noise and 296 (61.2%) living in the dormitory not exposed to traffic noise - the control one. The students did not differ significantly by gender and life style but they differed by age (females in the control group were older), length of stay in an apartment (longer in the control area) and by the exposure to several noise sources (besides traffic noise, also tramway noise, noise from neighbors and noise from entertainment facilities).

Subjective Response, Psychosocial Well-Being and Annoyance

Subjective response was assessed by the authorized „Noise annoyance questionnaire„ using validated 5 grade noise annoyance verbal scale [17,18]. The different sources of environmental noise were quantified. The validated 5 grade scale (Not at all; Slightly; Moderately; Very; Extremely), was developed and recommended by experts from ICBEN (The International Commission on the Biological Effects of Noise) team [18]. The questionnaire comprised personal (age, gender, education), behavioral (smoking, coffee and alcohol consumption), and questions focused on the characteristics of residential environment (localization, construction and surrounding of residential buildings, the location and amenities of the apartment, window orientation to quiet and noisy streets and the length of stay in the apartment). It also included questions on possible non-auditory health effects (noise annoyance from different sources, interference with various activities and sleep disturbance) and subjective assessment of health troubles (headache, nervousness and irritability, difficulties in falling asleep, the use of different types of medications, the presence of cardiovascular diseases and overall assessment of the health status) [17].

The 24-hour dietary consumption and energy expenditure were assessed by a Food Frequency Questionnaire. The other important demographic, behavioral and psychosocial factors (age, gender, family history, hormonal contraception use, perceived psychogenic stress, smoking, alcohol consumption, etc.), blood pressure and cholesterol levels were included in the Cardiovascular Risk Questionnaire. The sum of points from both questionnaires formed the complex variable Cardiovascular Risk Scores [8].

Assessment of the obesity markers

All participants underwent a physical examination at enrolment, including measurement of anthropometric parameters according to a standard protocol (barefoot, with light clothes on). Height, weight (electronic scale), waist (WC) and hip circumferences (HC) were assessed by standard methods, BMI (body mass index) and WHR (waist/hip ratio) were calculated. WC was measured at the umbilicus to the nearest cm with the subject standing and breathing normally. Hip circumference was measured as the maximum circumference around the buttocks.

BMI was calculated as weight (kg) divided by height (m^2). WHR was calculated by waist circumference (WC) (cm)/hip circumference (HC) (cm).

The amount of body fat is an exact indicator of the nutritional status and its excessive amount indicates the presence of overweight and obesity. The percentage of body fat was assessed by Futrex analyzer of body composition, based on the principle of light interaction with body tissues (Near Infrared Radiation Technology - NIR). The assessment involves application of the optic detector to the biceps of the dominating shoulder. The signal is immediately processed by an indwelling computer. The apparatus is calibrated for a hydrostatic method and provides printouts of the assessed and required data - a direct digital readout of percent body fat, lean mass, percent water and recommended maximum weight [19].

Bioimpedance analysis (BIA) was used as well using two devices, Omron BF306 (manual multifrequency analyzer) and InBody 720 (full body multifrequency analyzer).

Omron BF306 is handheld device, based on multifrequency bioimpedance method and measures the body in a form of one whole cylinder. Measured subject held electrodes in his forearms and Omron estimated the absolute amount of fat mass and the body fat percentage (Omron Healthcare Co, 2011) [20].

InBody 720 uses multiple frequency bioimpedance method and method of electrode placement to directly measure the body in a form of five separate cylinders (trunk, arms and legs). User was required to grasp and step on the electrodes and low current was transmitted through his body. Each segment was measured separately and final data were counted from values of every single segment, using computer software (Biospace Co, 2006) [21].

We applied the cut-off values: BMI ≥25kg/m^2, WC >94cm (men) />80cm (women), WHR >1.00 (men) / >0.80 (women), body fat ≥20% in men and ≥25% in women [22, 23].

Statistical analysis

Statistical evaluation comprises the methods of descriptive statistical analysis, associations among categorical and continuous variables by t-test, analysis of variance (ANOVA) and multivariate analysis (multiple linear, multiple logistic regressions). Crude and adjusted odds ratios (risk, relative probability of an event) and 95 % confidence intervals were calculated. Statistical packages Epi Info™, Version 7.1.1.1, 2013, S-Plus 6.0 and IBM SPSS version 24 were implemented.

RESULTS

Noise exposure objectification

The indicators estimated from Bratislava strategic noise map were L_{DEN}=66 dB vs L_{DEN}=54 dB ($p<0.05$) (EUROAKUSTIK, 2017, www.hlukovamapa.sk) (Figure 1) [16].

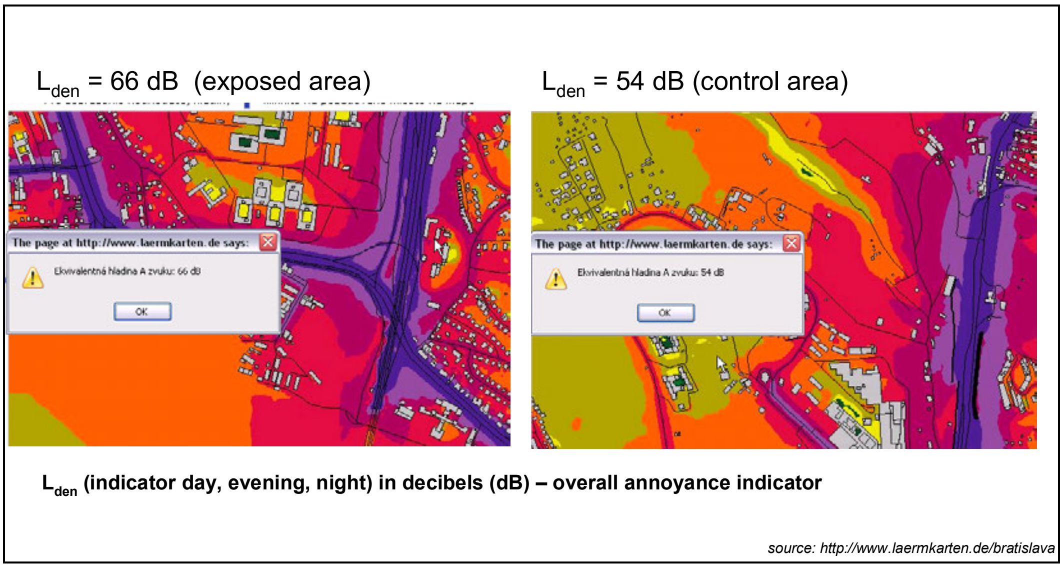


Figure 1: Exposed and control areas in Bratislava agglomeration

(EUROAKUSTIK, 2017, www.hlukovamapa.sk)

The monitoring of sound levels in the exposed area, with particular reference to the evening time bands showed the levels above the limit especially in the time interval when the noise is acting particularly troublesome for students [24] (Table 1).

In the composition of the traffic flow the number of passenger cars was predominant; there were also trucks, buses and trams, which are particularly noisy with its squealing effect [25].

The sound levels were significantly lower in the control area ($p < 0.05$) (Table 2). The traffic flow comprised of passenger cars and buses, but no trams. The traffic was much quieter than in the exposed area.

Table 1: Sound levels in the exposed housing facility, April 2015

Time intervals	Sound level L_{Amin} (dB)	Sound level L_{Amax} (dB)	Sound level L_{Aeq} (dB)	Road traffic flow composition
17.00-18.00	58.6	75.5	67.5	A 5460, B 36, L 60, T 72
20.00-21.00	52.1	81.3	66.9	A 4644, B 12, L 12, T 60

Legend: A - automobile, B - bus, L - lorry, T - tram

Table 2: Sound levels in the control housing facility, April 2015

Time intervals	Noise level L_{Amin} (dB)	Noise level L_{Amax} (dB)	Noise level L_{Aeq} (dB)	Road traffic flow composition
17.00-18.00	41.5	68.3	50.4	A 108, B 12, L 0, T 0
20.00-21.00	41.7	69.9	53.6	A 60, B 12, L 0, T 0

Legend: A - automobile, B - bus, L - lorry, T - tram

Students in the exposed housing facility were significantly more annoyed by road traffic noise (OR_{MH}=4.1, 95% CI=3.2-5.2), railway noise (trams) (OR_{MH}=2.0, 95% CI=1.6-2.7), by noise from neighborhood (OR_{MH}=1.6, 95% CI=1.3-1.9), entertainment facilities (OR_{MH}=4.1, 95% CI=3.2-5.2), noise from industry (OR_{MH}=2.4, 95% CI=1.9-3.1). There was no significant difference concerning noise annoyance from house construction and aircraft noise (Table 3).

Table 3: Annoyance risks from different community noise sources (year 2015)

Noise annoyance (type of noise)	**Risks in 2015** OR (95 % CI)
Road traffic	$^{+}$4.11 (3.2-5.2)***
Neighborhood	$^{+}$1.61 (1.3-1.9)***
Entertainment facilities	$^{+}$ 4.11 (3.3-5.2) ***
House construction	$^{+}$ 1.06 (0.8-1.4)
Railways	$^{+}$2.0 (1.6-2.7)***
Aircraft	1.4 (0.71-1.16)
Industry	$^{+}$ 2.4 (0.8-2.5)***

Legend: *** $p < 0.001$, + Mantel-Haenszel weighted odds ratio CI = confidence interval; OR = odds ratio

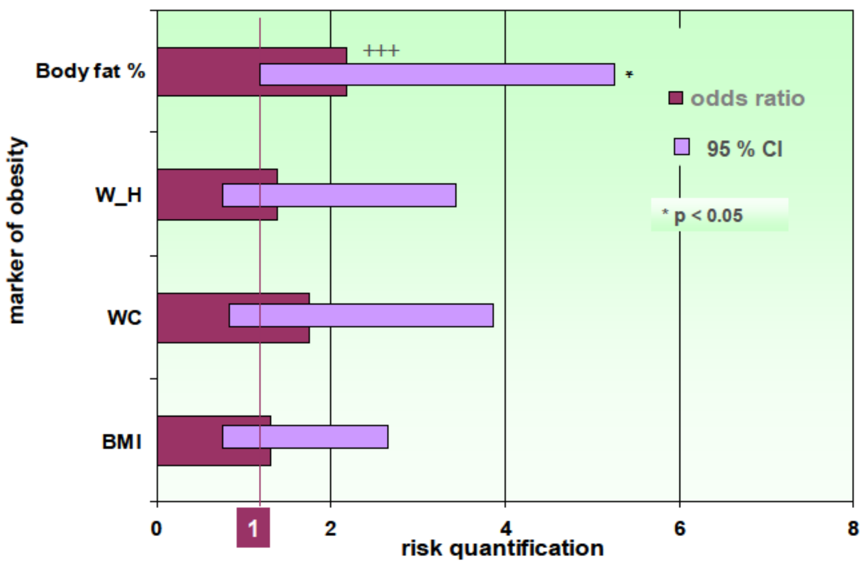
Road traffic noise (Figure 1) disturbs falling sleep and causes awakening (OR=2.3 (95% CI 1.48-3.58). Hypnotics intake was not significant due to young age of our respondents (Table 4).

Table 4: Sleep disturbance from road traffic noise (year 2015)

Sleep disturbance from road traffic noise	Risks in 2015 OR (95 % CI)
Falling asleep	+2.5 (1.9-3.3)***
Awakening	2.3 (1.5-3.6)***
Rest disturbance	+ 2.8 (2.2-3.6) ***
Hypnotics intake	1.4 (0.7-2.9)

Legend: *** $p < 0.001$, + Mantel-Haenszel weighted odds ratio CI = confidence interval; OR = odds ratio

The bivariate analysis showed higher levels of obesity markers in the group exposed to traffic noise compared to the control one (Table 5). The results were significant for percentage of body fat assessed by NIR method in the categorical analysis in men (OR=2.19 (95% CI 1.1-4.75), p=0.048), even after adjustment for complex variable Cardiovascular Risk Scores including the most important behavioral, psychosocial and nutritional factors assessed by a separate questionnaire (Figure 2).



+++ Adjusted for Cardiovascular Risk Scores in logistic regression

Figure 2: Markers of obesity and traffic noise exposure in men (n = 124)

Percentage of body fat assessed by NIR method was positively associated with traffic noise exposure in multiple linear regression (ß=1.320, p=0.02, r^2=0.14) and multiple logistic regression in the total sample with the cut off for body fat ≥20% (AOR=1.76 (95% CI 1.17-2.66), p=0.007) after adjustment for gender and the complex variable Cardiovascular Risk Scores.

Table 5: Markers of obesity in different traffic noise exposures (n = 484)

Variable	Exposed group (n = 188)*	Control group (n = 296)*	p-value
Gender N (%)			
Male	54 (28.72)	70 (23.65)	0.21
Female	134 (71.28)	226 (76.35)	
Age (years) **			
Male	22.89 ± 1.48	22.55 ± 0.97	0.07
Female	23.22 ± 1.99	23.05 ± 2.61	0.62
Body mass index - BMI ($kg.m^{-2}$) ***	22.49 ± 7.97	21.78 ± 4.35	0.21
Waist circumference (WC)***	75.20 ± 10.82	74.33 ± 11.22	0.41
Waist hip ratio (WHR) ***	0.78 ± 0.09	0.78 ± 0.09	0.66
Percentage of body fat ***			
NIR method	21.20 ± 5.9	20.10 ± 7.00	**0.08**
BIA Omron	19.14 ± 5.42	18.57± 6.02	0.31
BIA InBody	18.47±11.68	18.54± 10.76	0.95

* There are missing values for each variable category
** Average age in the sample (arithmetic mean ± standard deviation)
*** Average value in the sample (arithmetic mean ± standard deviation)

DISCUSSION

There are not so many studies investigating relations among community noise (especially road traffic noise) and obesity and the other metabolic outcomes. The results have been controversial. In the city of Plovdiv, Bulgaria, the study was aimed to determine the association between road traffic noise exposure and self-reported body mass index among 513 residents (18–83 years) and the relative risks of obesity were 1.03 (95% CI=1.01–1.05) among all participants and 1.05 (95% CI=1.01–1.09) among long-term residents. Future research is necessary in order to overcome the limitations of this study (low response rate, self reported BMI, crude questions about sleep disturbance and nutritional habits) [15].

In a large study of an urban population in Oslo they found no support for an association of traffic noise with obesity in the total population. However, among women they found a statistically significant interaction between noise exposure and noise sensitivity, suggesting that noise sensitivity has an effect modifying role in the association between noise and risk of obesity in women. Road traffic noise was statistically significantly associated with both general and abdominal obesity markers among highly noise sensitive women [14].

In Stockholm county central obesity was also associated with exposure to railway and aircraft noise and a particularly high risk was seen for combined exposure to all three sources of traffic noise [26]. The strength of the study was the large sample size of 5, 712 respondents, detailed questionnaire and medical examination on markers of obesity and statistical analysis. The limitations could be cross-sectional design, uncertainties in noise exposure assessment, lack information on exposure modifiers, such as façade and window insulation as well as bedroom location and the sample was enriched by the persons with a family history of diabetes. The risk appeared particularly high for aircraft noise and in those with concomitant exposure to different sources of traffic noise. Those findings are of importance for the understanding of noise-induced cardiovascular effects and open up the possibility of a wide variety of other types of adverse health effects.

The recent study by Foraster et al., 2016 on the large sample of the population-based Swiss cohort on Air Pollution and Lung and Heart Diseases in Adults (SAPALDIA), was the first study to explore the impact of transportation noise annoyance on physical activity, a behavioral pathway through which noise may in part affect cardiometabolic diseases in addition to the direct (physiological) stress pathway. The 10-year transportation noise annoyance (NA) was associated with a 3.2% (95% CI=6%–0.2%) decrease in moderate physical activity per 1-noise annoyance rating point and was related to road and aircraft NA at night in cross-sectional analyses. The longitudinal association was stronger for women, reported daytime sleepiness or chronic diseases [27]. The main strength of the study was the use of a prospective population-based cohort with rich data.

The limitations of our study are the young age, short duration of stay and the relatively small sample size. The strength is in the detailed questionnaire and examination on markers of obesity including body fat assessment with different methods and precise noise exposure assessment. Amount of body fat is an exact indicator of the nutritional status and its excessive amount indicates the presence of overweight and obesity. Several techniques are used for fat mass prediction, but they differ in validity and applicability. Screening tests require fast and non-invasive measurements. Analysis of fat mass showed significant differences between the methods we used. The highest values of body fat percentage in our study were measured by the NIR method, which correlates best with noise exposure. Sevcikova et al., 1994 in comparing study confirmed usability of Futrex device (NIR method) in college students and possibility of monitoring nutritional status during treatment and health programs in individuals and population [19]. Bioimpedance analysis using InBody, in a contrast to the other methods, can estimate the amount of visceral fat [21]. The results of visceral fat from InBody will be analyzed in the samples from years 2016, 2017 and in the future. In the future we would like also to explore the impact of noise annoyance on physical activity that was assessed precisely by a CINDI questionnaire.

The future research is necessary in order to overcome limitations and extent its inferences to the general population.

CONCLUSION

Students from the exposed group were more annoyed by road traffic noise disturbing their sleep and causing awakening. The obesity markers were higher in the group exposed to traffic noise significant for body fat assessed by NIR method in men in the categorical analysis, even after adjustment for complex variable Cardiovascular Risk Scores.

After taking into account study limitation and finalization of the results in the future, we would like to formulate the proposals and interventional procedures and effectively target the preventive measures in the vulnerable groups of teenagers and young adults.

Acknowledgements

The research was partially supported by grant Y.A.B.S. (Youth and Parents Behavioral Survey in Slovakia) O-15-101-/0001-00. Travel grant to attend the 12th ICBEN Congress on Noise as a Public Health Problem in Zurich (June 18-22, 2017) has been sponsored by the International Commission for Acoustics ICA.

REFERENCES

[1] Murphy, E., King, E.A. (2014) *Environmental Noise Pollution. Noise Mapping, Public Health, and Policy*. San Diego: Elsevier.

[2] Ziaran, S. (2008) *Protection of man from vibration and noise*. (in Slovak) Bratislava: Slovak Technical University.

[3] Evandt, J., Oftedal , B., Krog, N.H, Nafstad, P., Schwarze, P.E., Aasvang, G.M. A (2017) Population-Based Study on Nighttime Road Traffic Noise and Insomnia. *SLEEP,* 40 (2),
DOI: https://doi.org/10.1093/sleep/zsw055

[4] Fritschi, L., Brown, L. A, Kim ,R., Schwela, D., Kephalopoulos, S. (2011) *Burden of disease from environmental noise. Quantification of healthy life years lost in Europe.* Geneva: World Health Organization. http://www.who.int/quantifying_ehimpacts/publications/e94888.pdf

[5] Belojevič, G., Sarič-Tanaskovič, M. (2002) Prevalence of arterial hypertension and myocardial infarction in relation to subjective ratings of traffic noise exposure. *Noise & Health* , 4, 33–37

[6] Babisch W. (2008) Road traffic noise and cardiovascular risk. *Noise & Health* , 10(38), 27–33

[7] Jarup, L., Babisch, W., Houthuijs, D., Pershagen, G., Katsouyanni, K., Cadum, E. et al. (2008) Hypertension and exposure to noise near airports: the HYENA study. *Environmental Health Perspectives,* 116, 329–333

[8] Sobotova, L., Jurkovicova, J., Stefanikova, Z., Sevčíkova, L., Aghová, L. (2010) Community response to environmental noise and the impact on cardiovascular risk score. *Science of Total Environment*., 408 (6), 1264-1270

[9] Basner, M., Babisch, W., Davis, .A, Brink, M., Clark, C., Janssen, S., Stansfeld, S. (2014) Auditory and non-auditory effects of noise on health. *Lancet*, 383(9925),1325-1332

[10] Babisch, W. (2014) Updated exposure-response relationship between road traffic noise and coronary heart diseases: a meta-analysis. *Noise & Health* , 16(68):1–9.

[11] Sørensen, M., Andersen, Z.J., Nordsborg, R.B., Becker, T., Tjønneland, A., Overvad, K., et al. (2013) Long-term exposure to road traffic noise and incident diabetes: a cohort study. *Environmental Health Perspect*ives 121(2), 217-222.

[12] Eriksson, C., Hilding, A., Pyko, A., Bluhm, G., Pershagen, G., Östenson, C.G. (2014) Long-term aircraft noise exposure and body mass index, waist circumference, and type 2 diabetes: a prospective study. *Environmental Health Perspecives*. 122(7), 687-94.

[13] Pershagen, G., Pyko, A., Eriksson, C. (2014) *Exposure to traffic noise and central obesity*. Paper presented at the 11th ICBEN International Congress on Noise as a Public Health Problem, Nara, Japan

[14] Oftedal, B., Krog, N.H., Pyko, A., Eriksson, C., Graff-Iversen, S., Haugen, M., Schwarze, P., Pershagen, G. Aasvang, G,M. (2015) Road traffic noise and markers of obesity – a population-based study. *Environmental Research*. 138,144-153.

[15] Dzhambov, A., Dimitrova, D. (2015) Road traffic noise exposure association with self-reported body mass index. *Noise Control Engineering Journal*, 63, 572-581.

[16] EUROAKUSTIK: Web page Strategic noise maps, accessed on 18 March 2017: http://www.hlukovamapa.sk/strategicka-hlukova-mapa-bratislavskej-aglomeracie.html

[17] Sobotova, L., Jurkovicova, J., Volekova, J., Aghova, L. (2001) Community noise annoyance risk in two surveys. *International Journal Occupational Medicine and Environmental Health*, 14 (2), 197–200.

[18] Fields, J. M., De Jong, R. G., Gjestland, T., Flindell, I. H., Job, R. F. S., Kurra, S., et al. (2001). Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation. *Journal of Sound and Vibration*, 242(4), 641-679.

[19] Sevcikova, L., Aghova, L., Stefanikova, Z., Jurkovicova, J. (1994) Methods for assessment of depot body fat. *Hygiena*, 39, 345-351.

[20] Omron Healthcare Co. (2011) User's manual. Kyoto. Japan.

[21] Biospace Co. (2006) InBody 720 The precision body composition analyzer. User's manual. Seoul, Republic of Korea.

[22] WHO Technical Report Series 894. (2000) Obesity: Preventing and Managing the Global Epidemic. World Health Organization: Geneva, Switzerland.

[23] Lohman, T.G. (1992). Advance in Body Composition Assessment. Champaign, IL: Human Kinetics Publishers.

[24] The Ministry of Health Decree Nr. 549/2007 laying down details on the permissible values of noise, infrasound and vibration requirements and the objectification of noise, infrasound and vibration in the environment (in Slovak).

[25] Panulinova, E., Harabinova, S. (2014). Monitoring of Tram Traffic Noise in the Small Curve Radius. *Applied Mechanics & Materials,* 617, 120-123.

[26] Pyko, A., Eriksson, Ch., Oftedal, B., Hilding, A., Östenson, C.G.,. Krog, N.H. et al. (2015) Exposure to traffic noise and markers of obesity. *Occupational and Environmental Medicine*, 72, 594-601.

[27] Foraster, M., Eze, I.C., Vienneau, D., Brink, M., Cajochen, C., Caviezel, S. et al. (2016) Long-term transportation noise annoyance is associated with subsequent lower levels of physical activity. *Environment International,* 91, 341-349.