

## **Objectification of auditory and non-auditory effects of environmental noise from different sources in a sample of Slovak students**

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### **ABSTRACT**

Various noisy activities may be responsible for auditory and non-auditory effects on individuals. The study is aimed to quantify the effects of social noise exposure (personal music players (PMP), high noise exposure events) and road traffic noise in the sample of Slovak students. There were 1003 university students (306 males, average age 23.09±2.23) enrolled into the study so far; 347 in the housing facility exposed to road traffic noise ( $L_{Aeq} = 67.6$  dB) and 656 in the control one ( $L_{Aeq} = 53.4$  dB) in Bratislava. From the total sample 794 (79.16 %) students reported the use of PMP in the last week; average time of 286 minutes. There was a significant difference in PMP use between the exposed (85.6 %) and the control group (75.8 %) ( $p=0.01$ ). Among PMP users 26 % exceeded the LAV (lower action value for industry = 80 dB). On a pilot sample of volunteers ( $n=41$ ) audiometry testing was performed indicating hearing threshold shift at higher frequencies in 22% of subjects. The results showed the importance of social noise as well and the need for prevention and intervention.

### **INTRODUCTION**

The growing impact of exposure to environmental noise on health is one of the major health risks of present time. It concerns mainly the population living in urban areas, where there is a high level of traffic noise and the noise from other sources, such as construction, industry, entertainment facilities and neighbourhood [1]. This negative factor of the environment is different from other pollutants, its levels are still increasing and it affects humans constantly, during the time specified for relaxation and sleep. Noise levels annoy people also during recreation, leisure time or at social activities. The range of issues that may be associated with exposure to excessive noise is really wide. Prolonged exposure to environmental noise in the range between 60 - 90 dB can promote non-specific reactions of the organism, especially in the vegetative, endocrine and regulatory field [2, 3, 4, 5, 6].

In addition to exposure to environmental noise the voluntary or social noise exposure is now very important. This type of exposure is currently a major problem, especially among adolescents and young adults. Various leisure time activities (often listening to music on high-volume level with personal music players (PMP) and regular visiting of events with high noise exposure intensity), can have auditory effects on individuals (temporary or permanent

hearing threshold shift, hearing loss), or non-auditory effects (annoyance, sleep disorders, nervousness, irritability, high blood pressure) [1, 3, 5, 6,7].

With increasing duration of exposure increases the number and severity of hearing losses, which is often irreversible and there is a permanent displacement of the hearing threshold. Non-specific effects of noise are manifested by neurotisation of the organism and there are changes in the mental area, mainly manifested by mental disorders, disbalance, irritability and depression [2].

## **AIM OF STUDY**

The study is aimed to analyse the social noise exposure in the group of 20-25 years old individuals vulnerable to noise sources in exterior and interior. We focused on how often and how loudly our respondents use personal music players (PMP), mp3, mobile phones, how often they visit events of high intensity noise exposure and we evaluated auditory and non-auditory effects resulting from exposure to social and traffic noise in the selected sample of Slovak university students living in Bratislava.

## **MATERIAL and METHODS**

The research was conducted at the Institute of Hygiene Medical Faculty Comenius University in Bratislava, Slovakia. We used the method of subjective evaluation using a standardized anonymous questionnaire and methods of objectification by direct measurement of noise levels using hand-held sound analyser with frequency analysis software.

### **Study Subjects**

The followed subjects constituted a homogeneous group of the population with respect to age, education and lifestyle. Probandes were young and healthy individuals, students of the 4th and the 5th year of the Faculty of Medicine, Comenius University in Bratislava. The group consisted of 1,003 subjects, 697 (69.49%) females and 306 (30.51%) males. The average age was  $23.14 \pm 2.02$ . All students have temporary or permanent residence in Bratislava. Probandes from the exposed group stayed at the college dormitory Družba Comenius University (CU). This group included 347 (34.60%) subjects. Probandes from the control group stayed at the college dormitory of Ladislav Stur, Stare Grunty, CU. This group included 656 (65.40%) university students. Exposed housing facility – student dormitory is situated near the major transportation route, the main thoroughfare with railway transport; control housing facility – student dormitory in a quiet area with surrounding greenery. Probandes significantly differed by age, by traffic noise exposure, flat location in relation to noise exposure, position of a flat in the floor height, length of stay in the given area, windows orientation, windows types and satisfaction with flat surrounding and the use of PMP.

### **Exposure doses from social noise**

In the estimation of exposure doses from PMP we used the methodology by Portnuff et al. (2011 to 2013) [8, 9]. Respondents rated subjective intensity and frequency of exposure of personal music players (PMP). We examined what type of headphones they prefer (earphone or headphones) and at what volume level they listen to their PMP. They also rated how often they attend events with high noise exposure (e.g. rock concerts, discos, sport events) and how often they do noisy housework and whether they play a musical instrument).

### **Noise annoyance questionnaire**

We used a validated methodology for subjective evaluation of noise annoyance and interference with various activities. We assessed the sleep quality and psychosocial well-

being in relation to noise exposure. Respondents filled in validated "Noise annoyance questionnaire", using a 5-point scale to reflect various issues related to auditory and non-auditory effects arising from noise exposure [10, 11]. We focused mainly on sleep disturbance, noise annoyance from various sources and interference with activities of daily living. Based on data collected from targeted validated questionnaire, we evaluated the environmental, behavioral and psychosocial factors in students with permanent or temporary residence in Bratislava.

Questionnaires and objective examinations were voluntary for each of the respondents. Study participants also gave their consent to use the information for research purposes

### **Exposure assessment**

We used the method of objectification by direct measurement of noise levels using hand-held sound analyzer with frequency analysis software.

The measurements, maximal, minimal and equivalent sound levels were made in the exposed and in the control area in the Slovakian capital Bratislava. All measurements were recorded according to the valid legislation 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, and falling asleep). Measurements were recorded during spring period at working days (Tuesday) two times on each site.

### **Hearing Examination**

Hearing examination was provided in cooperation with ENT specialists for volunteers in the specialized Out-patient Department for Otorhinolaryngology in Bratislava. Probands were examined by subjective audiometric method in which the hearing was checked by electro-acoustic device - audiometry. The basic examination of the threshold tone audiometry establishing a threshold hearing for pure tones (lowest stimulus intensity that produced by the examined audio response). For determining the hearing threshold for pure tones were used diagnostic audiometer MAICO MA 52. This audiometer allows investigate overhead lines at frequencies of 250-6000 Hz and bone conduction at frequencies 500-1000-2000-4000 Hz. During the examination the probands were settling into a quiet chamber, respectively audiometric cabin in medical office. The chamber is specially constructed that its walls prevent the penetration of sounds. It is used for audiometric testing tone audiometry, in particular for determining the hearing threshold for pure tones and meeting the essential parameters, in particular the desired attenuation of the intensity of sounds. It corresponds to ISO 266: 1997 ISO 389-3: 2016<sup>th</sup>.

### **Statistical Analysis**

To evaluate the results, we used methods of descriptive, bivariate and multivariate statistics to identify mutual associations between lifestyle factors, psychosocial, biological, behavioral and environmental factors and statistical programs Epi Info <sup>TM</sup>, Version 7,1,1,1, 2013, and S-Plus 6.0.

## **RESULTS**

The monitoring of sound levels in the exposed area showed the levels above the national and international limits in the afternoon and in the evening time interval 17.00-18.00 and 20.00-21.00 ( $LA_{eq}$ =67.6; 64.7 dB) [12,13]. Sound levels in the control area were significantly

lower ( $p < 0.001$ ) ( $L_{Aeq} = 53.4; 54.3$  dB). The higher sound levels in the evening interval could be due to other noise sources (e.g. entertainment facilities) (Table 1, 2).

**Table 1:** Sound levels in the exposed housing facility, April 2016

Time intervals	Sound level $L_{Amin}$ (dB)	Sound level $L_{Amax}$ (dB)	Sound level $L_{Aeq}$ (dB)
17.00-18.00	53.2	85.8	67.6
20.00-21.00	49.0	82.4	64.7

**Table 2:** Sound levels in the control housing facility, April 2016

Time intervals	Noise level $L_{Amin}$ (dB)	Noise level $L_{Amax}$ (dB)	Noise level $L_{Aeq}$ (dB)
17.00-18.00	41.6	69.0	53.4
20.00-21.00	44.8	73.5	54.3

From the total sample of respondents, 794 (79.16%) students reported listening to PMP in the last week for the average time of 285 minutes. There was a significant difference in PMP use between the exposed (85.59 %) and the control group (75.76 %) ( $p = 0.0002$ ) and also in the duration of listening to PMP in minutes ( $286 \pm 367$  vs  $292 \pm 367$ ) ( $p < 0.55$ ), but it was not significant between genders ( $p = 0.08$ ).

About 16 % of students listen to the music on the loudness level 4 (they cannot hear the speech or even the traffic) and 86% use earbuds. There was not significant difference between the loudness level of PMP or in the duration of time spent at most events with high noise exposure between the exposed and control group.

The significant difference was in the type of headphones; earbuds are more often used by students from the exposed area (more than 90 % of students) ( $p = 0.01$ ) like headphones. Ear bud insert phone types are more harmful according to SCENIHR (2008) and increase the sound level by 7-9 dB [14]. Based on the subjective assessment the reduced hearing ability indicated 25.72% of subjects from exposed location and 22.02% of subjects in the control location. ( $p = 0.23$ ). The presence of subjective hearing impairment of PMP users was not significantly higher (23.99 %), than in the non-PMP users (20.67 %) ( $p = 0.4$ ).

From activities with high intensity of noise exposure most students took part in household and garden work ( $n = 438$ ), where they spent on average  $447 \pm 689$  minutes. The second most frequent activity was visiting a cinema ( $n = 374$ ), where students spent on average  $194 \pm 379$  minutes per month. The third one was visiting discotheques ( $n = 300$ ) where they spent on average  $457 \pm 661$  minutes per month. The fourth most preferred activity was the visit of rock concerts ( $n = 146$ ), where respondents spent on average  $244 \pm 368$  minutes per month. Most of the time, subjects ( $n = 143$ ) devoted to sport events, where they spent on average  $479 \pm 760$  minutes per month. Students spent  $459 \pm 642$  minutes playing musical instrument ( $n = 125$ ),  $129 \pm 107$  minutes visiting classical music concerts ( $n = 59$ ) and  $303 \pm 350$  minutes in sport shooting ( $n = 11$ ).

Students from the exposed group to road traffic noise spent at the cinema about  $244 \pm 650$  minutes per month, compared with subjects in the control group who spent in the cinema on average  $170 \pm 98$  minutes per month ( $p = 0.08$ ). There was no significant difference between the duration of time spent at the other events with high noise exposure between the exposed and the control group.

In cooperation with the ENT specialist we performed audiometric testing on a pilot sample of volunteers - university students ( $n = 41$ ), in which we found indicated hearing threshold shift in higher frequencies in 22% of subjects.

The prevalence of audiometric hearing impairment is defined as a threshold average greater than 20 dB hearing level in adults, in children it is 16 dB according to Niskar [12]. This threshold exceeded 9 (22%) subjects in the examinations on frequency 8000 Hz in the right ear and on the left on 5 (12%) subjects (Figure 1, 2).

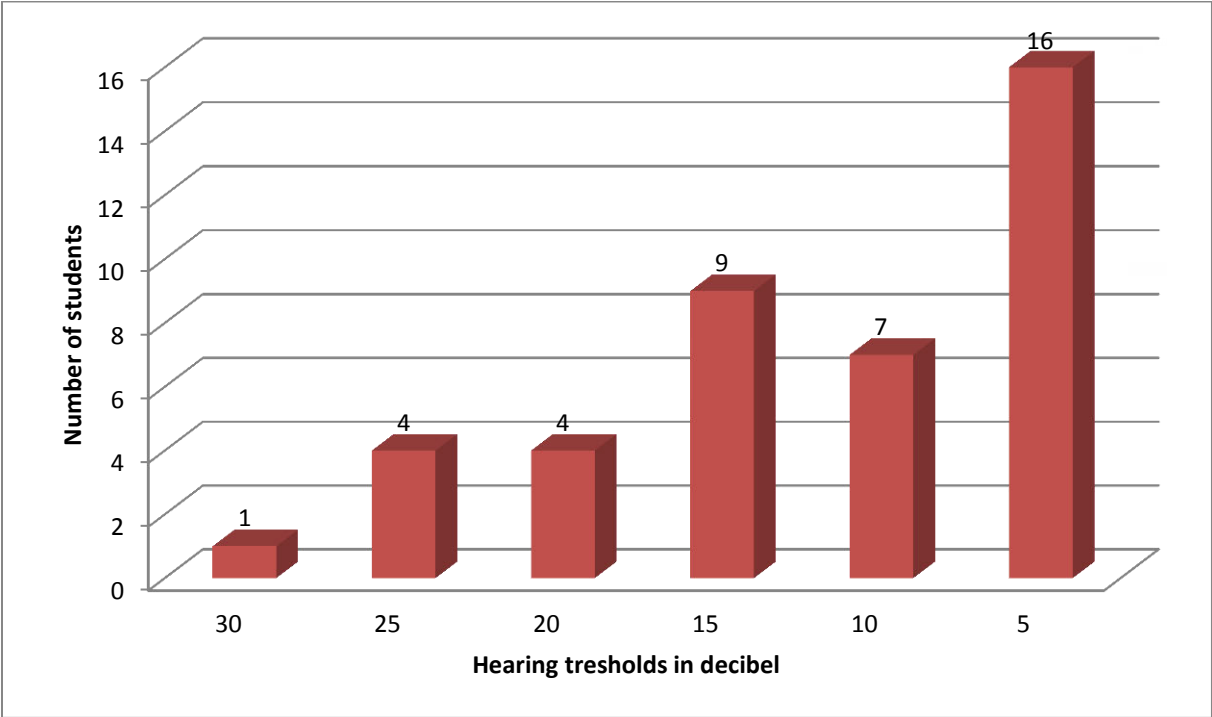


Figure 1. Hearing thresholds for pure tones 8000 Hz - right ear

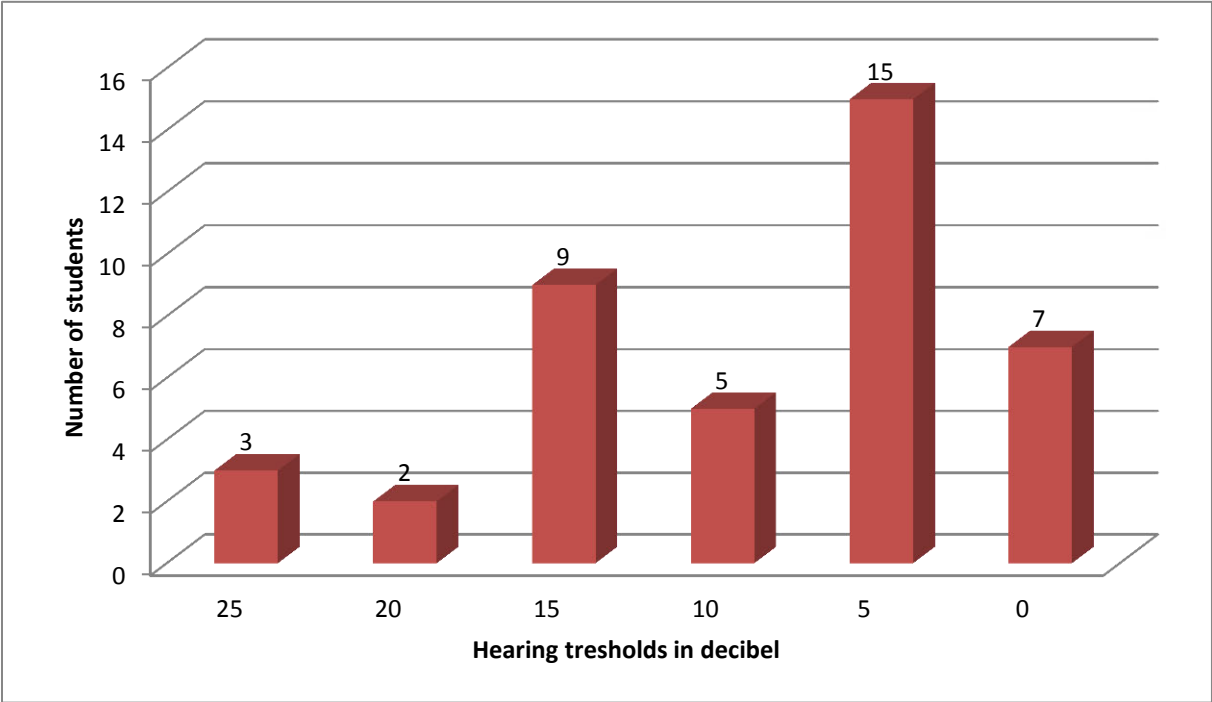


Figure 2. Hearing thresholds for pure tones 8000 Hz - left ear

We calculated also threshold averages: low-frequency average (500, 1000, and 2000 Hz) on the left and right ear, high-frequency average on the (3000, 4000, 6000, and 8000 Hz) left and right ear. In evaluation of the results the methodology from Niscar study [15] was used, where low-frequency hearing loss (LFHL) was defined as low pure tone average (LPTA) of at least 16 dB HL, and high frequency hearing loss (HFHL) was defined as high pure tone average (HPTA) of at least 16 dB HL. Normal hearing was defined as 0 - 15 dB, slight loss 16 -25 dB, mild loss 26-40 dB, moderate loss 41-65 dB and severe loss 66-95 dB. Because we have very small group of young healthy volunteers, the results of audiometric tests were only in the first three categories.

Our probands had decreased hearing in the higher frequencies of 6000 Hz and 8000 Hz bilaterally and also in the lower frequencies of 1000 Hz in the right ear and 2000 Hz bilaterally (Figure 3, 4) (Table 3, 4).

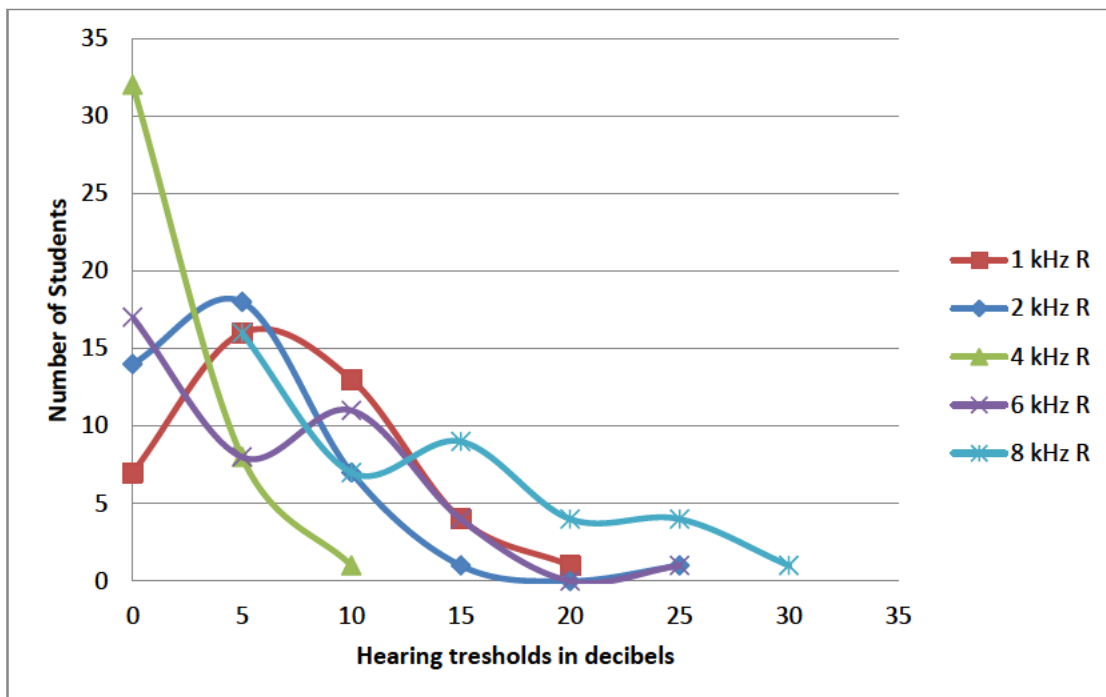


Figure 3. Hearing on 1 kHz, 2 kHz, 4 kHz, 6 kHz, 8 kHz – Right ear

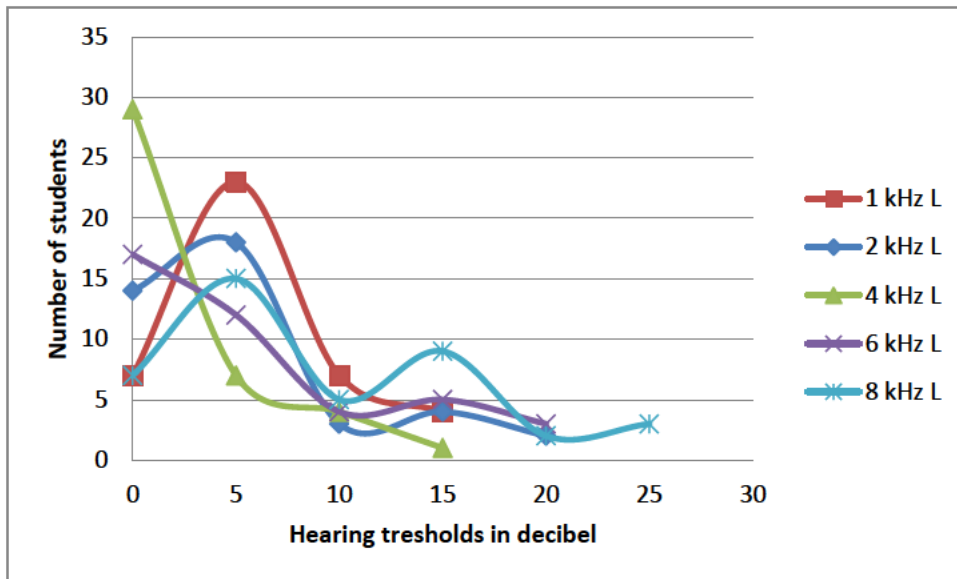


Figure 4. Hearing on 1 kHz, 2 kHz, 4 kHz, 6 kHz, 8 kHz – Left ear

Table 3: Prevalence of hearing threshold shifts, Right ear

Frequency, kHz	0-15 dB (Normal)	16-25 dB (Slight)	25 and more dB (Mild)
0,5	100%	0%	0%
1	97,6%	2,4%	0%
2	97,6%	2,4%	0%
4	100%	0%	0%
6	97,6%	2,4%	0%
8	78%	19,5%	2,5%

Table 4: Prevalence of hearing threshold shifts - Left ear

Frequency, kHz	0-15 dB (Normal)	16-25 dB (Slight)	25 and more dB (Mild)
0,5	100%	0%	0%
1	100%	0%	0%
2	95,1%	4,9%	0%
4	100%	0%	0%
6	92,7%	7,8%	0%
8	87,8%	12,2%	0%

Of those volunteers who attended audiometric testing, more than 43% exceeded the LAV by listening to PMP. In this group the decreased hearing in 28 % of subjects was found.

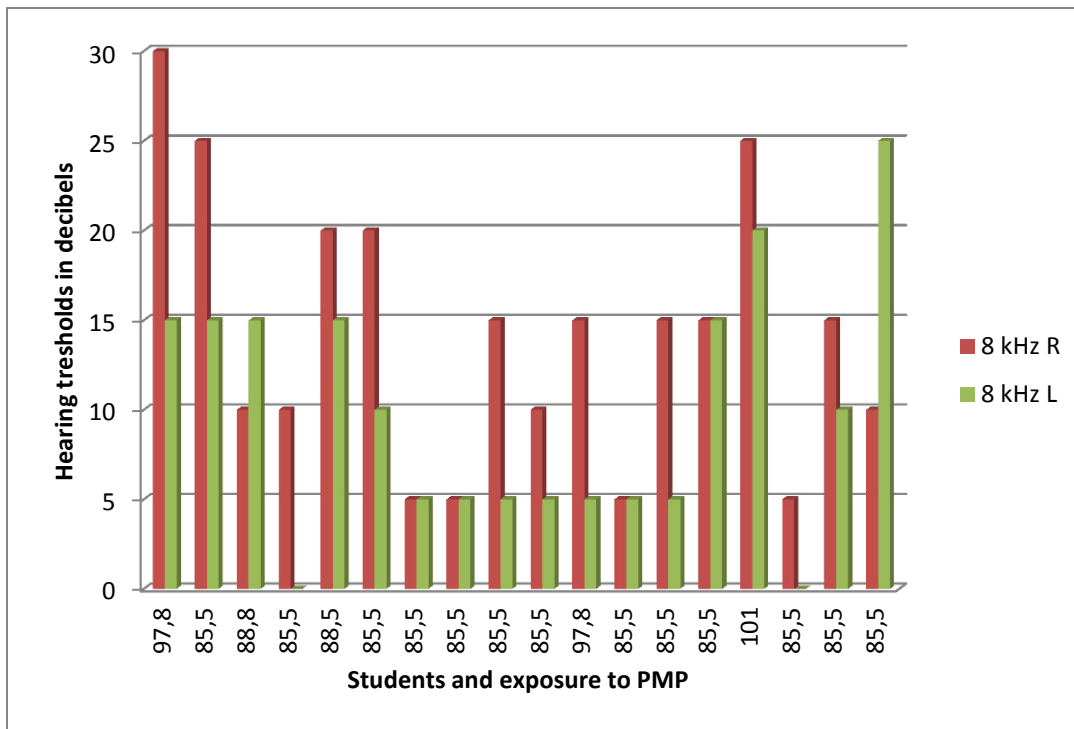


Figure 4. PMP listener students to high levels of sound and their audiometry examination at 8 kHz

## DISCUSSION

In our study, 79.16% of respondents reported listening to PMP in the last week, with an average listening time of 286 minutes, and 26% of PMP users exceeded LAV (lower action value for industry). On the basis of audiometric tests, with no branch examined the number of subjects, we recorded indicated hearing threshold shift at high frequencies in 22% of examined subjects. This vulnerable group of young people from the age of 20-30 is exposed to many sources of noise (from traffic, to construction facilities and neighbors, to social noise visiting events with high intensity of noise exposure and in addition to frequent listening to PMP on high volume). This group requires special attention in prevention of hearing impairment. In the future we would like to expand the study group to 100 subjects and to propose preventive measure. In the future we would also like to expand the study population to younger categories of teenagers (15 – 19 years old) who start very early with their “noise exposure”.

Our results are consistent with the results of other studies, reporting 88-90% of adolescents and young adults listening to PMP through headphones, especially ear plugs. Recent publications evaluated increased risk of hearing disorders in relation to the listening to PMP and the current incidence of hearing loss and tinnitus. The prevalence of hearing impairment caused by noise in adolescents and young adults was 17% and 29% in Europe [6]. Hearing threshold shift  $\geq 25$  dB at frequencies of one or more occurred in 7.3% of 177 subjects in Malaysia [16]. In a large sample of students from 9th grade primary schools in Bavaria ( $n = 1843$ ), the prevalence of audiometric notches was only 2.4% and indicated the need to follow this sample longitudinally or focus on the older age groups, such as university students [17]. Students in our group exposed traffic noise were listening to PMP more often than students in the control group (maybe trying to mask the noise from traffic or from the other noise sources). However, the volume of listening to PMP was not significantly different between those two groups.



## CONCLUSION

Our results have brought the evidence that exposure to environmental noise is now much more intense than in the past; besides traffic noise, there is also social noise from recreational leisure-time activities.

This exposure increases with the use of personal music players, which are now available to everyone, by MP3 player or by a smartphone. To this issue more attention should be given, because listening to music through PMPs is extremely popular, especially among young adults. This issue also includes the visits to various entertainment and recreational events with high noise intensity (cinema, concerts, discos, festivals).

It would be desirable to improve the scientific basis for the management of noise reduction and monitoring of the impact on health of residents.

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