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# Influence of risky and protective behaviors connected with listening to music on hearing loss and the noise induced threshold shift among students of the Medical University of Bialystok

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**A** – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

**Summary** **Background.** Currently, significant changes have occurred in the character of sound exposure, along with the properties of the group affected by it. Thus, primary care physicians have to keep in mind that a sizable group of young adults comprises groups in which the prevalence of hearing loss is increasing.
**Objectives.** The goal of the following study was to determine the auditory ability of the students attending the Medical University in Bialystok and to analyze their risky and protective behaviors relating to music consumption.
**Material and methods.** In total, 230 students (age: 18–26 years) completed a questionnaire about general personal information and their music-listening habits. Thereafter, pure tone audiometry at standard frequencies (0.25 kHz–8 kHz) was performed.
**Results.** Hearing loss was more frequent in subjects who listened to music at higher volumes ('very loud' – 22.2%, 'loud' – 3.9%, 'not very loud' – 2.1%, 'quiet' – 9.1%, $p = 0.046$). Hearing loss was more prevalent among those students who were living in a city with more than 50,000 inhabitants before starting higher education compared to the remaining subjects (7.95% vs. 0.97%, $p = 0.025$).
**Conclusions.** The study demonstrated that surprisingly few medical students suffer from hearing loss or a noise induced threshold shift. There is no correlation between risky behavior such as a lengthy daily duration of listening to music or the type of headphone used and hearing loss. Hearing screening tests connected with education are indicated in the group of young adults due to the accumulative character of hearing damage.
**Key words:** risky and protective behaviors, listening to music, mp3, hearing loss.

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## Background

Nowadays, it is well recognized that noise pollution is the most common environmental hazard accounting for hearing loss (HL). The harmful effects of long-term exposure to excessive sound have been documented, and limits have been established for the levels of noise permissible in the workplace [1]. Moreover, the occupational and environmental medicine physician works with management, health and safety, industrial hygiene, engineering and human resources to insure that all components of hearing loss prevention programs are in place [2]. However, over the last few decades, vast changes have occurred in the character of sound exposure and in the affected group. In fact, currently, when we think of exposure to noise, we are talking about a group of younger and younger people and an increase in noise exposure in their free time [1]. In the modern living environment, sounds such as music, if played very loudly, can be as dangerous to hearing as industrial noise. Attending concerts, clubs, live band performances and listening to personal listening devices (PLDs) have all been recognized as potentially harmful to hearing and have become the focus for prevention messages.

Recent studies suggest that "the earbud generation" might one day be the hearing loss generation. The European Union has taken action to reduce the risk, and the European Union's Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) has assessed that 5–10% of PLD users could develop permanent hearing loss if they listen to their devices at high volume for more than an hour a day [3]. The popularity of PLDs may be the most important risk factor for HL in youths and young adults listening to their favorite music [4]. According to the World Health Organization, adult onset of HL is the second leading cause of "years lived with disability" (4.6% of total), after depression, on a global level [3].

Considering the increasing attractiveness of PLDs, a minority of their users actually being at risk for hearing damage still equates to a relatively large population [1, 3]. The rapid development of digital technology has led to the production of new kinds of PLDs featuring improved sound quality at higher volumes. PLD users can avoid direct contact with strangers and the noises of the city and, at the same time, personalize their environment by using earphones. Social isolation and personalization affects an earphone user's state of mind during their daily activities [5]. In the majority of cases, noise damage increases with regular exposure to excessive noise [5]. PLD users are unaware of HL development or its presence until more significant damage occurs [3]. Symptoms of reduced hearing may lead to problems in one's later life. As HL may influence communication and interactive skills, it can harmfully affect education and the quality of life [4].

In literature concerning PLD use, there is a deficiency of research conducted on medical students, being future health care providers [6]. Students, in particular, were found to listen to music with PLDs in excess of safe listening levels and durations that posed a risk of hearing loss. On the other hand, regarding the health belief model, it is expected that medical students engage in behaviors to reduce danger and rather enhance protective behaviors connected with listening to music [7, 8].

# Objectives

Therefore, the aim of this study was to determine the hearing condition of students at the Medical University in Bialystok and to analyze their risky and protective behaviors relating to music consumption.

## Material and methods

A total of 230 students (from 18 to 26 years of age, both female and male) from the Medical University of Bialystok were asked to complete our questionnaire about music-listening habits, after which audiometry was performed. The analysis of risk factors associated with an audiometry examination is suitable for medical studies in diverse populations to better understand risk factors and comorbidities of hearing loss and hearing health care needs [9–11]. The Medical University of Bialystok Ethics Committee approved the study. The diagnostic survey method was applied in the research using a questionnaire devised by the authors of the study. Participation was voluntary and anonymous. The participants were informed about the nature and procedure of the study and provided written consent. The possibility to withdraw from the study at any time was clearly highlighted. To ensure anonymity, the consent, questionnaire and screening results were assigned numbers at random, different for each individual.

## Questionnaire

A questionnaire consisting of 26 single choice, multiple choice and yes/no answers was devised. It was divided into four parts. The first concerned general information, such as age, gender and course of study. The second part was focused on pathogen factors concerning: hearing impairment, diseases presently affecting the ear, diabetes, cranial injury, experience of ear pain or ringing, past infections which may affect hearing, mother's infections pregnancy. The third part contained questions concerning environmental factors, including: size of town in which the subject lives, traffic jams near the place of residence, presence of noise producing facilities, exposure to sources of noise, air pollution, intake of cholesterol and omega-3 fatty acids, as well as hypomagnesemia (connected with drinking coffee). The last part of the questionnaire inquired into music listening habits, involving: duration, volume of the music, frequency of attending concerts and clubs, types of headphones used and preferred type of music.

## Exclusion from further analysis

The subjects were asked about factors that may impact the results. Any positive response to these questions resulted in an exclusion from the research. The exclusion criteria included: noise exposure during the last 24 hours; previously diagnosed hearing impairment; any infection during the audiometry examination that may affect hearing performance; any missing data from the audiometry examination.

In total, 39 students (17%) were excluded, mostly due to noise exposure (30 students, of whom 15 were excluded on account of reporting to listening to music at high volumes).

## Audiometry

Pure tone audiometry was performed in a sound-treated room to ascertain students' air conduction thresholds for each ear for the frequencies of 1,000 Hz, 2,000 Hz, 3,000 Hz, 4,000 Hz, 6,000 Hz, 8,000 Hz, 500 Hz and 250 Hz across intensity ranges of 10–110 dB using 5 dB step intervals [11]. The AZ26 clinical impedance audiometer with standardized protocols (International Standard ISO 8253-1) was used. Output calibration verification was performed. The automatic procedure identified the lowest dB HL at which the subject responds positively to a tone 2 out of 3 times.

The examination was repeated whenever the threshold was higher than 25 dB to ensure the reliability of the responses [10]. The hearing threshold was marked on the printed audiogram, separately for the left and right ear.

## Hearing loss and NITS criteria

Hearing loss (HL), in the traditional meaning, concerns speech-affected frequencies (low-frequency hearing loss, LFHL) and high pure-tone average (high-frequency hearing loss, HFHL) and was specified according to criteria from Henderson et al. [10]. LFHL was present if, in at least one ear, the average threshold at 0.5, 1 and 2 kHz was > 15 dB HL, and HFHL – when the average threshold at 3, 4 and 6 kHz was > 15 dB HL in at least one ear.

Additionally, in order to analyze the results, we used the criteria for noise-induced threshold shifts (NITS), as described by Niskar et al. [11, 12]. An audiometric notch was considered to be present if, in at least one ear, (a) thresholds at 0.5 and 1 kHz of ≤ 15 dB and (b) a maximal threshold at 3, 4 or 6 kHz ≥ 15 dB higher than the highest threshold of 0.5 and 1 kHz, and (c) threshold at 8 kHz ≥ 10 dB lower than maximal threshold for 3, 4 or 6 kHz.

## Statistical analysis

The data obtained was analyzed statistically using the Chi-squared test and Fisher's exact test, where appropriate. Values were considered to be statistically significant at $p \leq 0.05$.

# Results

## Study population

After excluding 39 students (17%), mostly due to noise exposure during the last 24 hours, 191 students of the Medical University of Bialystok were included in this study. There were no statistically significant differences in the prevalence of HL or NITS gender-wise. The majority of the students described their hearing performance as 'good' (43.7%) or 'very good' (37.9%). The rest of the students rated their hearing as 'perfect' (3.2%), 'rather good' (10.5%) or 'sometimes fails' (4.7%). None of the students answered 'very bad' (Table 1). Before starting higher education, 46.1% of the students lived in a city > 50,000 citizens, 53.9% lived in a village or a city < 50,000 citizens. After starting higher education, the majority of the students (93.1%) lived in a city > 50,000 citizens, and the rest of students (6.9%) in a village or a city < 50,000 citizens (Table 1, Figure 1). More than half (57.1%) of the students described the intensity of traffic near their place of residence as 'medium', and the rest described it as 'large' (14.1%) or 'low' (28.8%). The majority (87.9%) of the students did not share their studies with work, and the remaining (12.1%) handled both studies and work. In the group of working students, 47.8% were exposed to noise at work, and 52.2% were not. Most of the students responded that they were not exposed to other sources of noise (88.6%) or a polluted environment (78.9%). Statistical analysis showed a significantly higher risk of HL among students living in a large city before starting higher education ($p$ = 0.025), but there was no additional noteworthy relationship between the other abovementioned features and HL or NITS.

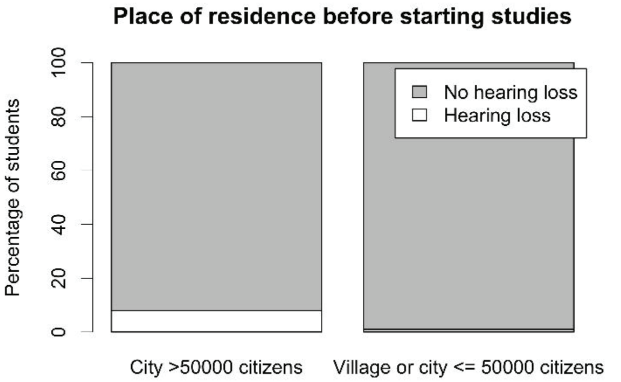


**Figure 1.** Prevalence of hearing loss related to a place of residence before starting higher education (%)

## Audiometry

LFHL in at least one ear was identified in 3% of the students, and HFHL in at least one ear in 2% of the subjects. Summing up, 4.2% of the students had either LFHL or HFHL, together described as HL. NITS was recognized in 5.8% of the students (Table 1).

## Eating behaviors of the subject group

Analyzing answers from the questionnaire, we found that 32% of the students stated they consumed animal fats every day, 35% – three times a week, 20% – twice a week, 4% – claimed that they do not eat animal fats, and the remaining 3% – did not answer this question. The majority of the students ate fish up to once a week (43% less than once a week, 39% once a week). Regarding drinking coffee – 32% of the students did not drink coffee or drank it very rarely, 7% – drank coffee once a week, 19% – 2–3 times a week, 27% – every day, and 15% – a few times a day. There were no statistically significant correlations between the dietary risk factors included in the survey and HL or NITS.

## Music listening habits

The majority of the students (60.7%) listened to music up to 2 hours per day, 27.1% of subjects listened to music from 2 to 3 hours a day, 7.1% – 4 to 5 hours a day, and 6% – 5 or more hours a day (Table 1). We did not find any significant correlation between the duration of listening to music and HL or NITS. Almost half of the students claimed they listened to music 'not very loud' (49%) and 40% – 'loud'. Only 5% reported listening to music 'very loud', and 6% – 'quiet'. There was a significantly higher risk of HL among students listening to music 'very loud' than the rest of the students ($p$ = 0.048) (Table 1, Figure 2).

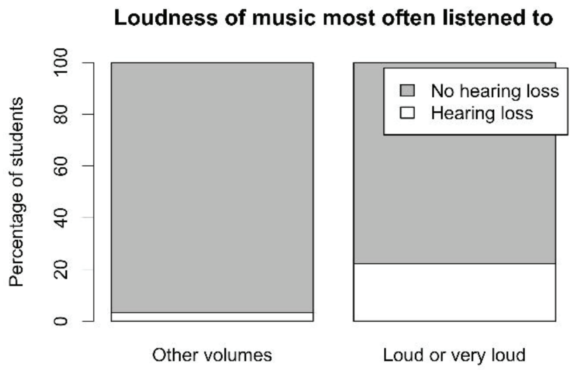


**Figure 2.** Prevalence of hearing loss related to loudness of music most often listened to (%)

Over half of the students used in-ear headphones, 25% reported using closed headphones, 9% – open headphones, and 4% – semi-open headphones. The remaining 5% of subjects left this question unanswered. Of the participants, 83% did not use earplugs during exposure to high levels of noise. There was no statistically significant correlation between listening to music using a specific type of headphones and HL or NITS.

**Table 1. Description of the study population**

| Variable | *n* | HL (%) | % of HL in the study population | *p*-value | NITS (%) | % of NITS in the study population | *p*-value |
|---|---|---|---|---|---|---|---|
| **Gender** | | | | | | | |
| Both | 191 | 8 (4.2) | | | 11 (5.8) | | 0.335 |
| Male | 71 | 5 (7.0) | 2.6 | 0.150 | 6 (8.5) | 4.1 | |
| Female | 120 | 3 (2.5) | 1.6 | | 5 (4.2) | 2.6 | |
| **Place of residence before starting higher education** | | | | | | | |
| In a city > 50,000 citizen | 88 | 7 (7.9) | 3.7 | 0.025 | 6 (6.8) | 3.1 | 0.788 |
| In a village or city < 50,000 citizen | 103 | 1 (1.0) | 0.5 | | 5 (4.9) | 2.6 | |
| **Subjective rating of hearing** | | | | | | | |
| Perfect | 6 | 0 (0.0) | 0 | 0.507 | 0 (0.0) | 0.0 | 1.000 |
| Very good | 72 | 4 (5.6) | 2.1 | | 5 (6.9) | 2.6 | |
| Good | 83 | 2 (2.4) | 1.1 | | 4 (4.8) | 2.1 | |
| Rather good | 20 | 2 (10.0) | 1.1 | | 2 (10.0) | 1.0 | |
| Sometimes fails | 9 | 0 (0.0) | 0 | | 0 (0.0) | 0.0 | |
| Very bad | 0 | 0 (0.0) | 0 | | 0 (0.0) | 0.0 | |
| No answer | 1 | – | – | | – | – | |
| **Duration of listening to music daily (in hours)** | | | | | | | |
| ≥ 5 | 11 | 1 (9.1) | 0.5 | 0.415 | 0 (0.0) | 0.0 | 0.351 |
| 4–5 | 13 | 0 (0.0) | 0 | | 0 (0.0) | 0.0 | |
| 2–3 | 51 | 1 (2.0) | 0.5 | | 1 (2.0) | 0.5 | |
| 1–2 | 46 | 3 (6.5) | 1.6 | | 5 (10.9) | 2.6 | |
| < 1 | 61 | 2 (3.3) | 1 | | 4 (6.6) | 2.1 | |
| Very rarely | 9 | 1 (11.1) | 0.5 | | 1 (11.1) | 0.5 | |

Table 1. Description of the study population

| Variable | *n* | HL (%) | % of HL in the study population | *p*-value | NITS (%) | % of NITS in the study population | *p*-value |
|---|---|---|---|---|---|---|---|
| **Loudness of music most often listened to** | | | | | | | |
| Very loud | 9 | 2 (22.2) | 1.0 | 0.048 | 1 (11.1) | 0.5 | 0.421 |
| Other volume level | 182 | 6 (3.4) | 3.1 | | 10 (5.5) | 5.2 | |
| **'Other volume level' of music listened to** | | | | | | | |
| Loud | 77 | 3 (3.9) | 1.6 | 0.046 | 2 (2.6) | 1.0 | 0.109 |
| Not very loud | 94 | 2 (2.1) | 1.1 | | 6 (6.4) | 3.1 | |
| Quiet | 11 | 1 (9.1) | 0.5 | | 2 (18.2) | 1.0 | |
| **Using in-ear headphones** | | | | | | | |
| Yes | 109 | 4 (3.7) | 2.2 | 0.716 | 4 (3.7) | 2.1 | 0.120 |
| No | 73 | 4 (5.5) | 2.2 | | 7 (9.6) | 3.7 | |
| No answer | 9 | | | | | | |
| **Using earplugs during exposure to high levels of noise** | | | | | | | |
| Yes | 33 | 0 (0.0) | 0.0 | 0.355 | 2 (6.1) | 1.0 | 1.000 |
| No | 158 | 8 (5.1) | 4.2 | | 9 (5.7) | 4.7 | |

## Discussion

Taking into consideration that HL may affect quality of life, the results of our research provide useful information on the influence of risky habits connected with listening to music on the state of hearing among the students of the Medical University of Bialystok.

The analysis of pure tone audiometry showed that HL and NITS were present in only a small percentage of students of the Medical University of Bialystok. Nevertheless, our subjects were young, and the effects of chronic exposure to hazardous recreational noise tends to accumulate over a lifetime without causing pain, gradually producing irreversible damage to the structures of the inner ear [13]. Conceivably, that results might change during next years of similar lifestyle of our subjects. A significant correlation between students' subjective assessment of hearing and HL or NITS was not found. None of our subjects rated their own hearing as 'very bad'. This might occur due to the fact that HL is noticeable in everyday life only if the loss is very significant [14–16]. Thus, even if the proposed criteria classified someone as having HL, a person might be unaware of this. We also cannot overlook medical knowledge concerning HL prevention, which may have led to more cautionary listening habits in this examined population. This fact underlines the important role of the primary care physician as "a hearing healthcare gatekeeper" in the identification and treatment of HL [14, 16]. Substantial changes will have to take place concerning the prevalence of a hearing screening and the knowledge of treatment and prevention available for improvement of hearing.

It is suggested that the type of headphones has an influence on the occurrence of HL or NITS, based on both pressure level and noise-attenuation capacity [13]. Usage of a different headphone classification may yield different results. In contrast, we found no correlation between using a specific type of headphones and HL or NITS; however, we distinguished only in-ear (also including earbuds) and various types of supra-aural earphones. Our findings may be limited by the unification of the study group to the students of one type of the university, especially a medical university. In our future research, we plan to compare the influence of different types of headphones on HL among students from different universities, including engineering and arts universities. Longitudinal studies with larger sample sizes are needed to confirm or refute the hypothesis that earbuds are potentially more harmful to hearing than supra-aural earphones.

Levey at al. (2013) state that those listening to music on portable devices at high volumes for long periods of time may be at risk of noise induced hearing loss [5]. Our research showed similar results, revealing statistically significant differences in the prevalence of HL among students listening to music at different volumes. In our study, we used the descriptive indication of loudness of listening to music. Loudness is the characteristic of a sound that is primarily a psycho-physiological correlate of physical strength. It is sometimes stated that loudness is a subjective measure, often confused with physical measures of sound strength, such as sound pressure, sound pressure level (in decibels), sound intensity or sound power. Several studies are accessible in literature assessing the sounds of PLDs in terms of equivalent sound pressure levels and the permissible dose of noise. These studies used various study designs and methods of measuring the maximum output levels of headphones (artificial ear vs. KEMAR system). As there is no standard for recreational noise, we decided to use the subjects' perception of loudness as 'quiet', 'not very loud', 'loud' or 'very loud'. On the other hand, our choice may be biased. However, all PMDs sold in Europe and all over the world do not have a loudness scale. What is controlled is the limited output level of PLD devices. Moreover, within research describing adequate problems, different methods of PLDs output level were used. Vogel et al. asked for a subjective description of volume control (as very low, ~25%, ~50%, ~75% or 100% or even "nearly using a noise-limiter") [16]. In Sulaiman's paper, subjects were asked to mark their usual listening volume on a 5.5-cm horizontal line that corresponded to 0–100% of the volume setting on their device [17].

In our research, there is a significantly higher prevalence of HL among students listening to music 'very loud' when comparing to others. Nevertheless, the students tended to choose answers from the middle of the range. Two extreme answers ('very loud' or 'quiet') were chosen very rarely, which might result from an assumption that music could be listened to at a high or low volume. To prevent ambiguous responses, an objective method of assessing loudness should be proposed in further studies [18].

Several researchers have showed that exposure to recreational noise would increase the risk of hearing impairment [9, 19–21]. Meyer-Bish (1996) found that those exposed to at least 7 h of music from a Walkman and suffered of hearing problems outnumbered the control group by 12% [9]. In our study, there were no incidences of HL among students using earplugs during exposure to high levels of noise, but this relation was not statistically significant. Again, longitudinal studies with larger sample sizes from different types of universities is needed in further study on the hearing condition of the students.

Statistical analysis revealed a higher prevalence of HL among students living in a large city before starting higher education ($p < 0.025$), which may be linked with higher noise levels in large cities compared to smaller towns. However, there is no statistically significant difference between the prevalence of HL among students currently living in a large city compared to those living outside large cities.

## Conclusions

The outcomes of our study showed that medical students are frequent PLD users, as other students, perform some potentially dangerous PLD listening behaviors. However, the research revealed that surprisingly few students have HL or NITS. There is no statistically significant increase in the prevalence of HL or NITS among medical students listening to music for long periods of time or those using any specific type of headphones; however, there is a higher prevalence of HL among students listening to music at high volumes compared to others. The results of the present study suggest the need of preventive hearing measurements for youths, connected with educational strategies about the detrimental, painless impact of listening to music at dangerously high volumes due to the accumulative character of hearing damage. Moreover, there exists a clear need for the development of educational programs for medicals students, being future health care providers, as well as for primary care physicians that focus on HL diagnosis and patient counseling. The primary care physician should keep in mind that the extensive group of adolescents and young adults represents a group in which the prevalence of HL is increasing and who may therefore benefit from screening.

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