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Frequency of the Audiometric Notch Following Excessive Noise Exposure

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The aim of the study was to determine the configuration of pathologic audiograms in patients with excessive noise exposure, and to calculate the frequency of notches in the audiogram in patients with and without excessive noise exposure by avoiding the effect of age-related hearing loss. We have analyzed 514 audiograms of 257 patients aged between 20 to 50 years: 240 patients (mean age of 38.7 years) with excessive noise exposure and 17 patients (mean age of 41.2 years) with notches in the audiogram, but without a history of excessive noise exposure. For statistical data analysis we have used the Chi-square test and Fisher exact test with the level of significance $p < 0.05$. Pathologic audiograms were classified into five different types: Slope at 4000 Hz (0.8%), Slope at 2000 Hz (15.1%), Notch at 4000 Hz (67.4%), Notch at 2000 Hz (0.8%), Flat (8.9%), and 7% were out of this classification. A total of 190 (79.2%) patients with excessive noise exposure had a notch in the audiogram. Left ear notches were the most common. Among the patients with notched audiograms, 91.8% had a history of excessive noise exposure, either occupational or nonoccupational, and 8.2% did not report any excessive noise exposure.

Keywords: audiometric configuration, notch, noise exposure.

1. Introduction

Acoustic trauma is a sensorineural hearing loss that can appear after a single exposure to a high-level noise impulse, whereas the noise-induced hearing loss (NIHL) is a sensorineural hearing impairment that develops over years of exposure to noise at moderately high levels (Pawlaczyk-Luszczynska *et al.*, 2013). NIHL is the second most common sensorineural hearing loss, after age-related hearing loss (do Socorro *et al.*, 2013). Exposure to very loud sounds can produce a permanent hearing loss by irreplaceably damaging the sensory cells (hair cells) and auditory neurons in the cochlea (Peppi *et al.*, 2011). The molecular and physiological mechanisms involved in the etiology or recovery from injury are not yet fully understood (Christie *et al.*, 2013). Overexposure to noise has been known to cause the occupational hearing loss. Such exposure is common in many industrial settings, such as construction, mining, agriculture, manufacturing and utilities, transportation, and the military (Kim *et al.*, 2005). Occupational hearing loss resulting from exposure to high noise levels depends not only on the exposure time but also on the frequency, intensity, and type of noise, continuous or impact (Ahmed *et al.*, 2001). It is usually bilateral, though occasionally unilateral (Kim, 2010). Noise traumas can result in two types of injury to the inner ear, depending on the intensity and duration of the exposure: transient attenuation of hearing acuity, a so-called temporary threshold shift, or permanent threshold shift (Oishi, Schacht, 2011). The notch in the audiogram, as a first sign of the occupational NIHL, typically develops at one of the high frequencies of 3000, 4000, or 6000 Hz, with recovery of 8000 Hz, and affects adjacent frequencies with continued noise exposure (Kirchner *et al.*, 2012). The presence of notched audiograms in the absence of positive noise exposure histories supports the idea that audiometric configuration is not a clear indication of the underlying pathology or etiologic pathway (Nondahl *et al.*, 2009).

Notched audiogram prevalence varied greatly by definition. Many authors reported notch prevalence including participants of different ages in their studies. We decided to determine the configuration of pathologic audiograms in patients with excessive noise exposure (> 85 dB), and to calculate the frequency of notches in the audiogram of patients with and without excessive noise exposure by avoiding the effect of age-related hearing loss.

2. Patients and methods

This retrospective study included a sample of 257 patients (231 males and 26 females), aged between 20 to 50 years, examined at the Department of Otorhinolaryngology, Division of Audiology, City General Hospital "8 September", Skopje, Republic of Macedonia. Ear, nose, and throat examination, as well as pure-tone audiometry were done during the period of January 2013 to May 2014. The sensorineural hearing loss in patients with a history of excessive noise exposure and presence of notched audiograms in patients without excessive noise exposure were the inclusion criteria. All patients were civilian, data on military personnel were excluded. Data on patients with temporary threshold shifts and a mixed hearing loss were also excluded. The pure-tone audiometry was performed with a Bell Plus (Inventis) audiometer and supra-aural headphones Telephonics TDH-39 in a sound proof booth. The hearing threshold was determined at the following frequencies: 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. We have used the audiometric configuration cited by Perez *et al.* (2000) to classify the pathologic audiograms, and some other algorithms for the audiograms that did not meet the criteria from the previous classification (Pittman, Stelmachowicz, 2003). The normal hearing was defined as thresholds of $\leq$ 20 dB hearing level (HL) at the audiometric frequencies from 250 to 8000 Hz, and the pathologic audiogram was defined as an audiogram with the hearing thresholds of > 20 dB HL at any of the frequencies (Adjamian *et al.*, 2012). A high-frequency "notch" was defined as a hearing threshold level at 3000 and/or 4000 and/or 6000 Hz; at least 10 dB greater than at 1000 or 2000 Hz and at 6000 or 8000 Hz (Coles *et al.*, 2000). For the statistical data analysis we have used the Chi-square test and Fisher exact test with the level of significance at $p < 0.05$.

3. Results

The total number of patients surveyed in our study was 257 (514 ears). A total of 154 patients (59.9%) were examined during periodic health visits or as a part of hearing conservation programs, and 103 (40.1%) were treated as outpatients or inpatients. The sample with excessive noise exposure included 240 patients: 229 (95.4%) males and 11 (4.6%) females. The mean age was 38.7 years. The sample without excessive noise exposure included 17 patients: two males (11.8%) and 15 (88.2%) females. The mean age was 41.2 years.

At the beginning, only the data for patients with excessive noise exposure were analyzed. We display separately the settings of excessive noise exposure for all patients (Table 1). Noise levels at workplaces or during recreational activities have not been measured, so we display estimated sound levels above 85 dBA (A-weighting) using data on measurements in identical situations. Use of firearm was the most common excessive noise exposure in both settings, either occupational (42.5%), or non-occupational (38.3% in target shooting and hunting). A total number of patients exposed to excessive noise in the occupational settings was 141 (58.8%): 131 (54.6%) males and 10 (4.2%) females, and in the non-occupational settings it was 99 (41.2%): 98 (40.8%) males and one female (0.4%).

The configuration of all pathologic audiograms has been determined. A total of 384 (80%) out of 480 audiograms were pathologic and 96 (20%) were normal. Audiograms of both ears were pathologic in 144 (60%) patients, only left ear audiogram was pathologic in 63 (26.2%) patients, and only right ear audiogram in 33 (13.8%) patients. In Fig. 1 we display the audiometric configuration of the pathologic audiograms.

There were five types of audiograms. In the slope configuration hearing loss gradually increases without recovery at higher frequencies. Three audiograms (0.8%) are of Type I (Slope at 4000 Hz). A total of 58 audiograms (15.1%) are of Type II (Slope at 2000 Hz). In our study, in the notch configuration hearing loss at a given frequency is 10 dB or more than that of the adjacent frequencies. Type III has a notch (dip) at 4000 Hz and Type IV has a notch at 2000 Hz. A total of 259 (67.4%) were of Type III and three audiograms (0.8%) were of Type IV. In the flat configuration the difference in hearing loss between all the frequencies tested did not exceed 15 dB. Thirty-four audiograms (8.9%) were of Type V. Only 27 audiograms (7%) did not meet the criteria from the previous classification and have been classified according to different algorithms. Fifteen audiograms are U-shaped. In the U-shaped audiograms one or more adjacent thresholds between 500 and 4000 Hz are $\geq$ 20 dB relative to the poorer threshold at 250 or 8000 Hz. Twelve audiograms are sloping. Thresholds in the sloping audiograms occurred at equal or successively higher levels from 250 to 8000 Hz and the

Table 1. Settings of excessive noise exposure and estimated sound levels above 85 dBA.

Settings (profession/hobby)	Sound level* [dBA]	males	females	total
		No. (%)	No. (%)	No. (%)
Occupational settings				
Firearm use (police officer/ security agency employee)	140–172	100 (41.7)	2 (0.8)	102 (42.5)
Manufacture worker	86–115	8 (3.3)	4 (1.7)	12 (5)
Construction worker	86–120	7 (2.9)	–	7 (2.9)
Textile worker	86–89	–	3 (1.3)	3 (1.3)
Forestry worker	86–110	2 (0.8)	–	2 (0.8)
Carpenter	86–115	2 (0.8)	–	2 (0.8)
Glazier	86–95	2 (0.8)	–	2 (0.8)
Locksmith	86–96	2 (0.8)	–	2 (0.8)
Farmer	86–99	2 (0.8)	–	2 (0.8)
Musician	86–110	2 (0.8)	–	2 (0.8)
Underground miner	86–100	1 (0.4)	–	1 (0.4)
Railway worker	86–90	1 (0.4)	–	1 (0.4)
Helicopter mechanic	86–98	1 (0.4)	–	1 (0.4)
Track driver	86–90	1 (0.4)	–	1 (0.4)
Night club employee	86–100	–	1 (0.4)	1 (0.4)
Non-occupational settings				
Target shooting	140–172	84 (35)	–	84 (35)
Hunting	135–165	8 (3.3)	–	8 (3.3)
Loud music listening	86–110	5 (2.1)	–	5 (2.1)
Blast injury (military explosion)	170–180	1 (0.4)	–	1 (0.4)
Using firecracker	125	–	1 (0.4)	1 (0.4)
Total		229 (95.4)	11 (4.6)	240 (100)

* Sources listed in Appendix.

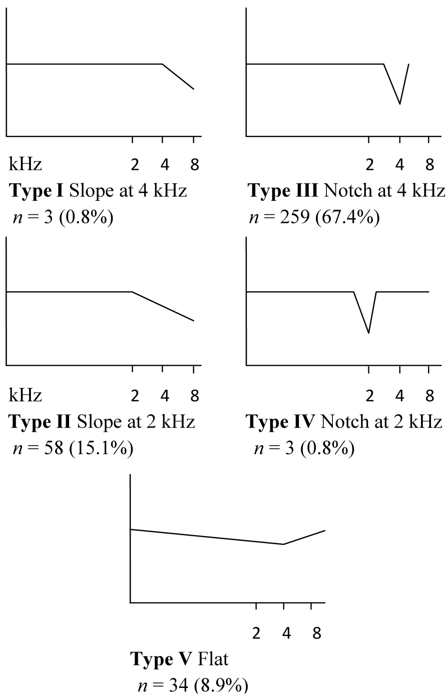

Fig. 1. Audiometric configuration following excessive noise exposure.

difference between the thresholds is always > 20 dB. In this case sloping at 2000 and 4000 Hz has been excluded.

The separately displayed audiogram configuration for patients with acoustic traumas and NIHL is as follows. Type I (Slope at 4000 Hz): 0.7% in acoustic traumas and 1.3% in NIHL; Type II (Slope at 2000 Hz): 13.1% in acoustic traumas and 22.8% in NIHL; Type III (Notch at 4000 Hz): 70.8% in acoustic traumas and 54.4% in NIHL; Type IV (Notch at 2000 Hz): 1% in acoustic traumas and none in NIHL; Type V (Flat): 9.2% in acoustic traumas and 7.6% in NIHL. According to the other algorithms, 5.2% are sloping and U-shaped in acoustic traumas, while 13.9% are sloping and U-shaped in NIHL.

We have calculated speech-frequency and high-frequency hearing loss in all the audiograms (Table 2). The speech-frequency hearing loss has been defined as a pure-tone mean of > 20 dB HL at 500, 1000, 2000, and 4000 Hz, and the high-frequency hearing loss has been defined as a pure-tone mean of > 20 dB HL at 3000, 4000, and 6000 Hz. A total of 175 (36.5%) out of 480 audiograms had the speech-frequency threshold mean > 20 dB, and 359 (74.8%) audiograms had the

Table 2. Speech-frequency and high-frequency hearing loss in all audiograms.

Average hearing threshold	Speech-frequency hearing loss	High-frequency hearing loss
	No. (%)	No. (%)
0–20 dB HL	305 (63.5)	121 (25.2)
21–40 dB HL	167 (34.8)	282 (58.8)
41–60 dB HL	8 (1.7)	65 (13.5)
> 60 dB HL	– (0)	12 (2.5)
Total	480 (100)	480 (100)
Total (0–20 dB HL)	305 (63.5)	121 (25.2)
Total (> 20 dB HL)	175 (36.5)	359 (74.8)
		$p < 0.001^*$
Total (all audiograms)	480 (100)	480 (100)

* Chi-square test

Table 3. High-frequency hearing loss and duration of noise exposure in occupational settings.

Degree of hearing loss	5–10 years	10–15 years	> 15 years	Total
	No. (%)	No. (%)	No. (%)	No. (%)
0–20 dB HL	–	2 (5.1)	–	2 (5.1)*
21–40 dB HL	8 (20.5)	5 (12.8)	10 (25.6)	23 (59)**
41–60 dB HL	4 (10.3)	3 (7.7)	4 (10.3)	11 (28.2)***
> 60 dB HL	–	–	3 (7.7)	3 (7.7)****
				p=0.569
Total No. (%)	12 (30.8)	10 (25.6)	17 (43.6)	39 (100)

* One patient was exposed to noise levels up to 100 dBA, and one patient to 110 dBA.

** Six patients were exposed to 100 dBA, three patients to 110 dBA, ten to 115 dBA, and four patients to 120 dBA.

*** Six patients were exposed to 100 dBA, two patients to 115 dBA, and three patients to 120 dBA.

**** One patient was exposed to 100 dBA, one patient to 110 dBA, and one patient to 115 dBA.

threshold mean > 20 dB HL. The high-frequency hearing loss is more common than the speech-frequency hearing loss.

A statistical analysis shows that there is a significant statistical difference between the number of audiograms with the high-frequency hearing loss and that with the speech-frequency hearing loss ($\chi^2 = 142.874$, $df = 1$, $p < 0.001$). We have compared the total number of audiograms with thresholds 0–20 dB HL and > 20 dB HL.

The degree of hearing loss in patients in terms of duration of noise exposure has been analyzed. It was impossible to make a homogeneous group in cases of firearm using because people used different kinds of weapon, some of them reported using firearm in occupational and non-occupational settings, and the frequency of shooting was different. No one reported a regular use of earmuffs or earplugs. The data on 99 patients with non-occupational noise exposure and 102 patients with firearm use in the occupational settings have been excluded, and only the duration of exposure and degree of hearing loss for 39 patients with the occupational noise exposure is displayed (Table 3). As hearing loss predominantly occurs at high frequencies, high-frequencies hearing loss (in the worse ear) has been shown for all patients. Most of the patients had hearing thresholds from 21 to 40 dB HL. We have not found a statistically significant difference between the groups of patients with different duration of excessive noise exposure and degree of hearing loss (Fisher exact test, $p = 0.569$) in patients with thresholds greater than 20 dB. In the statistical analysis we have included the subgroups with the degree of hearing loss of 21–40 dB HL, 41–60 dB HL, and > 60 dB HL, with different duration of noise exposure.

In further analysis data on patients with audiometric notch configuration but without a history of excessive noise exposure has been included. We have considered in our calculations only narrow, V-shaped notches, not wide, U-shaped notches. The patients were classified as having a notched audiogram when a notch was detected at least in one ear. A total of 190 (79.2%) out of 240 patients with excessive noise exposure had notches in one or both audiograms. A total of 72 patients (37.9%) out of 190 had bilateral notches and 118 patients (62.1%) had unilateral notches (259 notches were at 4000 Hz and three of them were at 2000 Hz). In the group of patients with unilateral notches, 79 (66.9%) patients had a left ear notch and 39 (33.1%) patients had a right ear notch. In Table 4 the presence of a notch in the audiogram in all patients, with and without excessive noise exposure, is displayed. A total of 190 (91.8%) patients out of 207 had a history of exces-

Table 4. Presence of a notch in the audiogram and noise exposure history.

Presence of notch in the audiogram	With excessive noise exposure	Without excessive noise exposure	p^*	Total
	No. (%)	No. (%)		No. (%)
Bilateral	72 (34.8)	3 (1.4)		75 (36.2)
Right ear	39 (18.8)	5 (2.5)		44 (21.3)
Left ear	79 (38.2)	9 (4.3)		88 (42.5)
Total	190 (91.8)	17 (8.2)	0.235	207 (100)

* Fisher exact test.

sive noise exposure and 17 (8.2%) patients did not report excessive noise exposure, either occupational or non-occupational (15 patients had notches at 4000 Hz and two patients had notches at 2000 Hz). In both groups left ear notches were the most common, and there is no statistically significant difference between the unilateral or bilateral presence of a notch in the groups ($p = 0.235$). We have compared the subgroups with a bilateral, right ear, and left ear notch, with and without an excessive noise exposure history.

A number of audiograms with the greatest hearing loss at 4000 Hz has been calculated separately. Some audiograms had the greatest hearing loss at 4000 Hz, but did not meet the criteria for notched audiograms. A total of 284 audiograms (74%) in patients with excessive noise exposure had the greatest hearing loss at 4000 Hz and 100 audiograms (26%) had it at other frequencies. In the group of patients without excessive noise exposure, 17 audiograms (77.3%) had the greatest hearing loss at 4000 Hz, and five audiograms (22.7%) had it at other frequencies. In both groups hearing loss was more common at 4000 Hz in comparison to other frequencies. A statistical analysis shows that there is no significant difference between the groups of patients ($\chi^2 = 0.119$, $df = 1$, $p = 0.729$).

We have also analyzed the presence of a tinnitus in all patients, but we have found data only for 145 patients: 128 ones with excessive noise exposure and 17 patients without excessive noise exposure (Table 5). In the case histories of 112 patients with excessive noise exposure no accurate records whether they experienced tinnitus or not have been found. A total of 85 (66.4%) out of 128 patients with excessive noise exposure had a tinnitus. The bilateral tinnitus was more prevalent than the unilateral one. In terms of the tinnitus quality, most of the patients experienced high-pitched whistling. There is no statistically significant difference in the unilateral or bilateral presence of a tinnitus between the analyzed groups ($p = 0.714$).

Table 5. Tinnitus localization in patients with and without excessive noise exposure.

Tinnitus localization	With excessive noise exposure	Without excessive noise exposure	p^*	Total
	No. (%)	No. (%)		No. (%)
Bilateral	51 (60)	5 (50)		56 (58.9)
Right ear	13 (15.3)	2 (20)		15 (15.8)
Left ear	21 (24.7)	3 (30)		24 (25.3)
Total	85 (100)	10 (100)	0.714	95 (100)

* Fisher exact test.

4. Discussion

Most of the patients with excessive noise exposure were males. Occupational noise exposure is common for men. They are more likely to work in places with a loud noise and also tend to have noisy hobbies. With intention of determining the audiometric configuration it was, decided not to include the data on patients older than 50 years, as after that age one can expect association of noise-induced hearing loss and age-related hearing loss. In a considerable proportion of the NIHL cases, especially after the age of about 50 years, the characteristic high-frequency notch is missing. Additional presence of a high-frequency hearing impairment due to other reasons has the effect of converting a noise-induced audiometric notch into a bulge (Coles *et al.*, 2000). The NIHL and age-related hearing loss often coexist in the same ear, however, the conditions under which these forms of hearing loss interact remain poorly understood (Kujawa, Liberman, 2006). Presbyacusis and noise exposure are strongly correlated, and presbyacusis may even overrule the effect of noise in hearing loss (Dudarewicz *et al.*, 2010).

The most common non-occupational excessive noise exposure in our sample was target shooting. We can notice that many people are exposed to excessive noise in recreational settings and they are not aware that noise can be dangerous to their hearing. A single gunshot (peak level) is approximately 140 to 170 dB (Rabinowitz, 2000). The noise induced hearing loss occurs when individuals are exposed to a noise that exceeds 85 dB (Sung *et al.*, 2013). Agencies which regulate occupational noise exposure almost universally specify a permissible 8 h equivalent average ($L_{A8,hn}$) exposure of 85 dBA (assuming 2000 h work annually) (Neitzel *et al.*, 2004). We use the term "noise-induced hearing loss" for patients who reported excessive occupational noise exposure. This is a retrospective study and we did not measure the noise level at the work places, therefore indirect estimation had to be used instead. It is estimated that workers in an 85 dB environment will have to speak loudly, while those in an 85–90 dB one will have to shout. As noise approaches 95 dB, communication only occurs with shouting even if the workers stand next to each other (Suter, 1986, cited by May, 2000).

In our study bilateral pathologic audiograms were more common than unilateral pathologic ones. NIHL presents as a gradual, symmetrical decline in hearing, even where the noise source is consistently on one side (Haboosheh, Brown, 2012). Our sample comprised both the NIHL and acoustic trauma cases (predominantly acoustic trauma) and there were many unilateral pathologic audiograms (40%).

The most common configuration type in our study was Type III, notch at 4000 Hz. Using the same classification in a sample of patients exposed to explosions

Perez *et al.* (2000) found 46% of audiograms with a downward slope configuration, 41% with a dip (notch) configuration, and 12% flat audiograms. Spremo and Stupar (2008) reported the following types: slope at 2000 Hz in 27.1%, slope at 4000 Hz in 25.9%, and flat type in 25.2% of acoustic trauma cases (individuals exposed to explosions). We could not compare their results strictly with those from our study because in our sample most of the patients had acoustic traumas, but mostly firearm noise exposure was reported, and only one patient had a blast injury. Other patients with blast injuries were excluded because of tympanic membrane perforations and the conductive hearing loss. Our results were similar to findings of Psillas *et al.* (2008) in patients exposed to the gunfire noise. They used another classification, and the most common audiogram type was the high frequency notch. The presence of high-frequency notches in the noise-induced hearing loss is well documented (Nelson *et al.*, 2005; Fausti *et al.*, 2009; Job *et al.*, 2012; Delecrode *et al.*, 2012; McBride, 2004; Harada *et al.*, 2008). In our study we did not find 6000 Hz notches. It is possible that 6000 Hz notches are transient and caused by chance. They are variable and of a limited importance (McBride, Williams, 2001).

The results from our study have also confirmed that hearing loss at high frequencies is more common than that at speech frequencies. We have defined the speech-frequency and high-frequency hearing loss similar to Agrawal *et al.* (2008). Analyzing the degree of a high-frequency hearing loss in terms of duration of excessive noise exposure and noise levels, we could not draw any conclusions, because this group of patients with occupational NIHL is very small.

The definition of the high-frequency notch in our study is the same as that used by Coles *at al.* (2000). In the published literature there are different definitions of the notch in the audiogram. Wilson and McArdle (2013) used a similar definition: thresholds at 2000 and 8000 Hz were both minimally at HLs 10 dB lower than (better than) the threshold at the notch frequency of interest 3000, 4000, or 6000 Hz. According to Twardella *et al.* (2013) a notch in an audiogram was considered to be present if in at least one ear the threshold values at 0.5 and 1 kHz were $\geq$ 15 dB HL (better), and the maximum (poorer) threshold value at 3, 4, or 6 kHz was at least 15 dB HL higher (poorer) than the highest (poorest) threshold value for 0.5 and 1 kHz, and the threshold value at 8 kHz was at least 10 dB HL lower (better) than the maximum (poorest) threshold value for 3, 4, or 6 kHz. To define the noise-induced threshold shift, Mahboubi *et al.* (2013) considered a notch to be present when the 4 kHz threshold was worse than 20 dB HL (i.e., 25 dB HL or worse), the 4 kHz threshold was at least 10 dB worse than the 2 kHz one, and the 4 kHz threshold was at least 10 dB worse than that of 8 kHz.

Unilateral notches in our sample were more prevalent than bilateral ones. Left ear notches were predominant. We can explain this by the fact that most of the patients were exposed to the gunfire noise. A right-handed shooter has his left ear closer to the muzzle and the left ear is more exposed to noise than the right ear, which is in the "acoustic shadow" of the head. Wilson (2011) reported an equal distribution of high-frequency notches between the right and left ears, and 4000 Hz notched audiograms were as common as or more common than bilateral notched audiograms.

The percent of the patients with a notch in the audiogram without a history of excessive noise exposure in our study was similar to other authors' findings. Even large population studies increasingly find non-normal high-frequency hearing including the characteristic NIHL-"notch" around 6000 Hz, also in subjects who do not report noise exposure incidents or activities (Borchgrevink, 2003). Nondahl *et al.* (2009) reported that approximately 11% of the participants did not have a history of excessive noise exposure. In our study most of the patients in this group were females. In the cases of recorded notched audiograms without excessive noise exposure many authors reported a bigger number of women than men (Nondahl *et al.*, 2009).

The bilateral tinnitus was more prevalent than the unilateral one, and the unilateral tinnitus was more common in the left ear. Pathologic audiograms of the left ear were also predominant. There is no statistically significant difference in the presence of a tinnitus between the groups of patients with and without excessive noise exposure. The prevalence of a reported tinnitus in patients with the noise induced hearing loss varies in wide ranges. A tinnitus may be present in over half of patients with the occupational NIHL (May, 2000). Steinmetz *et al.* (2009) reported a 22% presence of the tinnitus in plant workers. Rezaee *et al.* (2012) reported a 60% post-exposure tinnitus in military personnel during shooting practice.

It is very important to emphasize the fact that no patient in the sample reported a regular use of earmuffs or earplugs. Sound attenuation for earmuffs is 20 dB, and for earplugs is 15 dB (Coles *et al.*, 2000). For ear plugs attenuation depends almost completely on a proper instruction of insertion (Verbeek *et al.*, 2012). Hearing protectors attenuate the industrial impulse noise more effectively than they do the steady state continuous noise. This is due to the high frequency contents of impulses, which are attenuated effectively in earmuffs (Starck *et al.*, 2003).

4.1. Limitations of the study

This is a retrospective study and we analyzed only the audiometric configuration in patients who reported excessive noise exposure. We did not take into consideration individual susceptibility to the NIHL, health status, using ototoxic medications, smoking habits, etc. For patients with the occupational NIHL we did not have data on baseline audiograms and "standard threshold shifts", or possible co-exposure to noise and vibration, organic solvents or some other factors.

5. Conclusion

Notch configuration is the most common audiometric configuration in patients with excessive noise exposure. However, a notch in the audiogram may be present also in cases without excessive noise exposure. Estimated notch prevalence depends on the definition, so, there is a need of a unique definition of a notch in the audiogram. Patients with excessive noise exposure had hearing loss predominantly at high frequencies. In terms of the gender, most of the patients with excessive noise exposure were males. Excessive noise exposure is a significant public health risk even in non-occupational settings. Further studies could focus on hearing conservation programs.

Appendix.
Sources for noise levels

Centres for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH) http://www.cdc.gov/niosh/topics/noise/ http://www.cdc.gov/niosh/mining/userfiles/works/pdfs/2010-111.pdf
Occupational Safety and Health Administration (OSHA) https://www.osha.gov/Publications/3498noise-in-construction-pocket-guide.pdf https://www.osha.gov/dts/osta/otm/new_noise/index.html
World Health Organization (WHO) http://www.who.int/occupational_health/publications/occupnoise/en/
American Tinnitus Association (ATA) http://www.ata.org/sites/ata.org/files/pdf/Gunfire_Noise_and_Hearing_Protection_Kramer_June_02.pdf
American Speech-Language-Hearing Association (ASHA) http://www.asha.org/public/hearing/Recreational-Firearm-Noise-Exposure/
American Hearing Research Foundation http://american-hearing.org/disorders/noise-induced-hearing-loss/
Department of Environmental and Occupational Health Sciences http://depts.washington.edu/occnoise/content/generaltradesIDweb.pdf http://depts.washington.edu/occnoise/content/carpentersIDweb.pdf
Better Hearing Institute, Washington, DC http://www.betterhearing.org/hearingpedia/hearing-loss-prevention/noise-induced-hearing-loss
Medline Plus http://www.nlm.nih.gov/medlineplus/ency/patientinstructions/000495.htm
European Agency for Safety and Health at Work https://osha.europa.eu/en/sector/agriculture/noise
U.S. National Park Service http://www.nps.gov/grca/naturescience/upload/GRCA-07-05-SoundLevels-Helicopters.pdf
Health and Safety Authority http://www.hsa.ie/eng/Publications_and_Forms/Publications/Occupational_Health/The_Noise_of_Music.pdf
U.S. Army, Reserve Officer Training Corps (ROTC) http://www.umass.edu/armyrotc/Training/grenades.pdf
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