

Awareness among Medical Students on Noise Induced Hearing Loss after Prolonged Use of Personal Auditory Gadgets and the Audiological Evaluation of the Students with Hearing Loss

Rachith Reddy Pingili¹, B. Vijay Kumar²

¹House Surgeon, Kakatiya Medical College, and MGM Hospital, Hanamkonda, Telangana State

²Assistant Professor of ENT, Kakatiya Medical College, and MGM Hospital, Hanamkonda, Telangana State

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Corresponding Author: Dr. B. Vijay Kumar

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Abstract:

Background: Noise induced hearing loss (NIHL), a preventable cause of hearing, is fast growing in the student communities. The type of device of external auditory delivery system used, duration, volume used, and other risk factors play their role in producing NIHL. An attempt is made to assess the awareness level of noise induced hearing loss among medical students and evidence based assessment of hearing in them.

Aim of the Study: To understand the awareness among medical students about NIHL with the use of PADs and their effects on the hearing mechanism; to evaluate the audiological function of these students with the help of pure tone audiometry.

Materials: 110 medical students out of 463 were included and presented with a questionnaire on awareness of NIHL and their personal hearing problems. Demographic data is collected along with risk factors. Type of PAD used, its duration, and volume were recorded. The Objective and subjective assessment of audiological functions in them were done. All the data is analysed for comparison with other studies.

Results: Out of, 110 students, 48 (43.63%) were aged between 18 and 21 years and 62 (60%) were aged between 22 to 25 years. 71 (64.54%) students were females and 39 (35.45%) were males, with a male to female ratio of 1:1.82. Smoking habit was present in 19 (17.27%) students and not present in 91 (82.72%) students. Family history of hearing loss (HL) was present in 11 (10%) students and no family history in 99 (90%) students. Urbanites were 67 (60.90%) and rural students were 43 (39.09%).

Conclusions: Medical Students frequently using PADs for music at different volumes possessed sufficient information about impending HL and other ill effects of Health. Students were identified to have NIHL due to usage of PADs. Awareness about ill effects of PADs and road safety were possessed by majority of the students. Use of objective methods of hearing assessment should be undertaken to identify NIHL at the earliest in those who used PADs.

Keywords: Hearing, PAD, Sound, noise, audiometry and SNHL.

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Introduction

Noise-induced hearing loss (NIHL) among the medical students was found growing at an alarming rate and causing public Health issue. [1] During these modern times advancement in the music systems and personal auditory devices (PAD) were found to generate loud volumes of sound particularly in India. [2]

Such alarming increase in the PADs was possible due to increase in the usage of smart cell phones, and inbuilt provisions to connect to high volume generating PADS. [3] According to Shangliao Sun [4] a research worker in telecommunications working on Indology stated that the users of smart phones in India would reach to 1 billion by 2023

and by 2040 the number would be nearing 1.55 billion. The WHO estimated that the 1.1 billion younger populations aged below 35 years would be at risk of developing hearing loss all over the world due to their new listening habits while they used PADS. [5]

Studies have shown in the literature that when PADS are used at an intensity of more than 80dB (unsafe) levels young people develop NIHL initially temporary but later on leading to permanent loss.[6] But there was found no agreement among the research workers regarding the duration of exposure, safety thresholds, loudness intensity causing NIHL. [7] Occupational

exposure to noise defined by the Centre for Disease Control (Atlanta) guidelines, the level of noise permissible was 90db for 150 minutes. [8] Porntoff recommended what is known as 80-90 rule which envisages usage of PAD at 80% volume of the gadget for 90 minutes in a day. [9] Hair cells in cochlea convert the sound energy to electrical energy by the piezo-electric effect and the supporting cells provide the pool for regeneration of damaged hair cells. [10] Continuous exposure to high level sounds (>85dB over 8 Hours) will lead to damage or loss of hair cells and also degeneration of spiral ganglion cells (SGNs), though the susceptibility to noise induce hearing loss is different in different individuals. [11,12]

A temporary threshold shift (TTS) is noted in the hearing acuity due to damage to the hair cells and degeneration of auditory nerve fibers being reversible initially for a period. [13,14] Hearing acuity is measured with objective audiological tests like OAE (Otoacoustic emission), ABR Auditory Brain stem response) and DPOAE (distortion product otoacoustic emission). [15] In TTS patients both the ABR and DPOAE values would recover but with severe noise exposure over a long time would lead to necrosis of cochlear hair cells.

This results in permanent threshold shift (PTS). [16] The damage to hair cells becomes irreversible with the increase in the age of the individual as the cells lose their regeneration capacity. [17] NIHL also has its effects on the psyche of the individual resulting in restlessness, insomnia, and lack of concentration and adversely affects the quality of life (QoL).

Similarly improper use of headsets or earphones would lead to difficulty in interpreting the speech, tinnitus, vertigo and reduced acuity of hearing. [18] The present study is conducted to know the awareness about hearing loss among the medical students who are using PADs and their effects on the hearing mechanism of their ears. The present study was also conducted to evaluate the audiological function of these students with the help of pure tone audiometry.

Study Design: A cross sectional analytical study.

Study Setting: Department of ENT, Kakatiya Medical College and MGM Hospital, Hanamkonda, Warangal, Telangana

Study Duration: 09 months (September 2021 to May 2022)

Study Population: All the medical students were surveyed by using a questionnaire about loss of hearing awareness upon using PADS at Kakatiya Medical College and MGM Hospital, Warangal, Telangana.

Sampling sample size: Sample size is calculated by the formula $N = \frac{4pq}{d^2}$;

Where $p = 25\%$, prevalence taken from the study

$q = 70\%$, $d = 8$

Hence $n = 110$

Materials:

110 medical students studying in Kakatiya medical College, and MGM Hospital of Telangana state were included in this study. An institution ethics committee approval was obtained before undertaking the study, Ethics committee approved questionnaire was used to assess the awareness of the medical students about the hearing loss.

Inclusion Criteria:

Medical students belonging to all the years of MBBS course were included. Students belonging to all the age groups were included. Students using PADS were included. Students using the PADs for more than 08 hours were included.

Students who are willing to answer the questionnaire and participate in the survey were included. Students who are willing to undergo audiometry tests were included.

Exclusion Criteria:

Students not willing to participate were excluded. Students not willing to answer the questionnaire were excluded. Students who have undergone ear surgeries earlier were excluded. Students with impacted wax, external otitis were excluded. Students with PADs usage less than 08 hours were excluded. All the students were given a questionnaire containing 12 questions related to awareness of hearing loss on using PADs for prolonged times.

The questionnaire:

QUESTIONNAIRE TO ELICIT AWARENESS OF HEARING LOSS IN MEDICAL STUDENTS

1. Do you have difficulty in interpreting the spoken words of your friends?
2. Do you have difficulty in interpreting the spoken words of your teachers?
3. Do you have difficulty in hearing, If so right ear/ left ear/ both ears?
4. Do you have ringing sensation in the ears?
5. Do you use PADs, if so what is the lowest and highest intensity levels available on it?
6. If so how many hours do you use PADs?
7. What is the minimum intensity you use regularly?

8.	What is the maximum intensity you use regularly?
9.	Do you use external Hearing gadgets apart from PADs?
10.	Do you find it difficult to understand the lecture classes due to diminished hearing?
11.	Are you aware that PADs used at high intensity causes diminished hearing?
12.	Are you aware that there would be temporary threshold shifts in hearing upon use of PADs?
13.	Are you aware that there would be permanent threshold shifts in hearing upon use of PADs?
14.	Are you willing to undergo auditory evaluation tests in the Hospital?
15.	Do you use PADs at high intensity above 85 dB for more than 8 hours?
16.	Do your friends or other people say that you talk loud?
17.	Do your friends say that you tend to ask "What?" repeatedly in a conversation?
18.	Do your family members say that you tend to raise the volume of the TV?
19.	Do you know that listening to higher volumes on PADs cause HL?
20.	Do you know that living or working in high noisy environment causes HL?
21.	DO you know that continuously listening to high volumes of music leads to HL?
22.	Do you know that if you are listening to others voice in a low and muffled manner indicates that you have HL?
23.	Do you know that hearing ringing sensation in the ears is a sign of HL?
24.	Do you know that noise induce hearing loss is preventable?
25.	What is the minimum duration and intensity of noise that could cause HL in you?

All the students who were complaining of diminished hearing were subjected to pure tone audiometry. Air con-duction and bone conduction thresholds and a-b gap and pure tone average were recorded.

Analysis of Data: The data was entered into Microsoft excel sheet and analyzed using standard statistical packages. The tests used were measures of frequency, measures of central tendency (Mean and Median). Associations were tested using tests of significance like Chi square test and the independent sample t test.

Results: Demographics: The present study was a survey conducted in a Medical College among the medical students, a total of 463 students were

contacted and the questionnaire was distributed. Only 110/463 (23.75%) students responded, matched the inclusion and exclusion criteria and included in the study.

Among the 110 students 48 (43.63%) were aged between 18 and 21 years, 62 (60%) were aged between 22 to 25 years. 71 (64.54%) students were females and 39 (35.45%) were males with a male to female ratio of 1:1.82. Smoking habit was present in 19 (17.27%) students and not present in 91 (82.72%) students.

Family history of hearing loss (HL) was present in 11 (10%) students and no family history in 99 (90%) students. Urbanites were 67 (60.90%) and rural students were 43 (39.09%). (Table 1)

Table 1: Showing the demographic information in the study (n-110)

Observation	Number	Percentage	P value
Age in years			0.001
18 to 21	48	43.63	
22 to 25	62	60.00	
Gender			0.001
Male	71	64.54	
Female	39	35.45	
Smoking			0.001
Yes	19	17.27	
No	91	82.72	
Family history of HL			0.001
Yes	11	10	
No	99	90	
Lived in areas			0.001
Urban	67	60.90	
Rural	43	39.09	

There was no hearing loss in 102 (92.72%) of the students, mild hearing loss in 05 (04.54%), moderate in 02 (01.81%) and severe in 01 (0.90%) students. (Table 2)

Table 2: Showing the incidence of severity of HL in the subjects (n-110)

Grade	Number	Percentage	P value
Normal	102	92.72	0.001
Mild	005	04.54	0.001
Moderate	002	01.81	0.001
Severe	001	0.90	0.001

The response to the questionnaire was analyzed and tabled in Table 3 below. Questions number from 01 to 18 is related to the subject's personal complaints of hearing and information of usage of PADs and external auditory devices. Question numbers 19 to 25 are related to the awareness about NIHL and its

causes, and effects and prevention. It was observed that the awareness about NIHL was present in 60 to 75% of the medical students in this study. 25 to 30% of the students were not aware of the NIHL and its causes and effects. The remaining 05 to 15% students were uncertain. (Table 3)

Table 3: Showing the distribution of the answers to the questions in survey questionnaire (n-110).

Question number in Questionnaire	Number	Percentage	P value
1 Do you have difficulty in interpreting the spoken words of your friends?	02	01.81	0.001
Do you have difficulty in interpreting the spoken words of your teachers?	01	0.90	0.001
3 Do you have difficulty in hearing, If so right ear/ left ear/ both ears?	06	05.45	0.001
4 Do you have ringing sensation in the ears?	04	03.63	0.001
5 Do you use PADs, if so what is the lowest and highest intensity levels available on it?	Yes- 58 no- 52 40- 70	52.72 47.27	0.001
6 If so how many hours do you PADs?	04	03.63	0.001
7 What is the minimum intensity you use regularly?	40to50		0.001
8 What is the maximum intensity you use regularly?	60 to 75		0.001
9 Do you use external Hearing gadgets apart from PADs?	Yes-12 No- 98	10.90 89.09	0.001
10 Do you find it difficult to understand the lecture classes due to diminished hearing?	Yes-06 No- 94	05.45 85.45	0.001
11 Are you aware that PADs used at high intensity causes diminished hearing?	Yes- 28 No- 82	25.45 74.54	0.001
12 Are you aware that there would be temporary threshold shifts in hearing upon use of PADs?	Yes- 13 No- 97	11.81 88.18	0.001
13 Are you aware that there would be permanent threshold shifts in hearing upon use of PADs?	Yes- 14 No- 96	12.72 87.27	0.001
14 Are you willing to undergo auditory evaluation tests in the Hospital?	Yes- 110	100	0.001
15 Do you use PADs at high intensity above 85 dB for more than 8 hours?	Yes- 003 No- 107	02.72 97.27	0.001
16 Do your friends and other People say that you tend to talk loud?	Yes- 11 No- 99	10 90	0.001
17 Do your friends say that you tend to ask "What?" repeatedly in a conversation?	Yes- 004 No- 106	03.63 96.36	0.001
18 Do your family members say that you tend to raise the volume of the TV?	Yes- 007 No- 103	06.36 93.53	0.001
19 Do you know that living or working in high noisy environment causes HL?	Yes- 66 No- 54	60 49.09	0.001
20 Do you know that continuously listening to high volumes of music leads to HL?	Yes- 69 No- 41	62.72 37.27	0.001
21 Do you know that if you are listening to others voice in a low and muffled manner indicates that you have HL?	Yes- 42 No- 68	38.18 61.81	0.001
22 Do you know that hearing ringing sensation in the ears is a sign of HL?	Yes- 27 No- 83	24.54 75.45	0.001

23 Do you know that noise induce hearing loss is preventable?	Yes- 39 No- 71	35.45 64.54	0.001
24 What is the minimum duration and intensity of noise that could cause HL in you?	1 year- 55 2 years- 21 3 years-24	50 19.05 21.81	0.001
1. Do you think that use of PADs at high volumes affects the road safety of the	Yes- 72 No- 38	65.45 34.54	0.001

In this study usage of PADs, external auditory devices and ear phones was enquired among the students and found that 71 (64.54%) students were using PADs, 12 (10.90%) were using external PAD, car PAD was used by 22 (20%), (Table 4) 64 (58.18%) students were using PADs for less than 03 hours, 31 (28.18%) students were using between

03 and 05 hours and 15 (13.63%) students were using for 05 to 08 hours.

The volume of PAD used was less than 49% in 67 (60.90%) students, 50 to 69% in 39 (35.45%) students, 60 to 69% in 10 (03.09%) students and above 70% in 04 (03.63%) students (Table 4).

Table 4: Showing the risk factors in the survey conducted among the medical students (n-110).

Risk factors to HL	Number	Percentage	P value
PAD used			0.001
Earphones	71	64.54	
External PAD	12	10.90	
Car PAD	05	04.54	
Headphones	22	20	
Number of hours the PAD used			0.001
Less than 3 Hours	64	58.18	
3 to 5 Hours	31	28.18	
5 to 8 Hours	15	13.63	
Level of volume used on PAD			0.001
Less than 49%	67	60.90	
50 to 59%	39	35.45	
60 to 69%	10	09.09	
Above 70%	04	03.63	

In this study 51 (46.36%) of the students had air conduction thresholds between 0 and 05 dB, 20 (18.18%) had thresholds between 05 and 10dB, 18 (16.36%) had thresholds between 10 and 15dB, 14 (18.18%) had thresholds between 15 and 20dB, 05 (04.54%) had thresholds between 20 and 25dB and 02 (01.81%) had thresholds above 25dB (Table 5). Bone conduction thresholds were between 05 and 10dB in 60.90% of students, between 10 and 15dB in 16.36% of students, between 15 and 20 dB in 14.54% of students, between 20 and 25dB in 07.27% of students, and above 25 dB in 0.90% in

the study. (Table 5) Air bone gap was 0 to 10 dB in 76.36% of students, 10 to 15 dB in 10% of students, 15 to 20 dB in 14.54% of students, 20 to 25 dB in 04.54% of students, and above 25 dB in 01.81% of students. (Table 5) Pure tone average (PTA) was 05 to 10 dB in 82.72% of students, 10 to 15 dB in 08.18% of students, 15 to 20 dB in 06.36% of students, 20 to 25 dB in 01.81% of students, and above 25 dB in 0.90% of students. (Table 5) 03 students had their air, bone conduction thresholds, a-b gap and PTA more than 25dB in the study. (Table 5)

Table 5: Showing the Audiological evaluation of the medical students (n-110)

Audiological evaluation	Number	Percentage	P value
Air conduction threshold			0.001
0 to 05 dB	51	46.36	
05 to 10dB	20	18.18	
10 to 15 dB	18	16.36	
15 to 20 dB	14	12.72	
20 to 25dB	5	4.54	
Above 25 dB	2	1.81	
Bone-conduction threshold			0.001
05 to 10 dB	67	60.9	
10 to 15 dB	18	16.36	

15 to 20 dB	16	14.54	
20 to 25 dB	8	7.27	
Above 25 dB	1	0.9	
a-b Gap			0.001
05 to 10 dB	84	76.36	
10 to 15 dB	11	10	
15 to 20 dB	8	14.54	
20 to 25 dB	5	4.54	
Above 25 dB	2	1.81	
PTA			0.001
05 to 10 dB	91	82.72	
10 to 15 dB	9	8.18	
15 to 20 dB	7	6.36	
20 to 25 dB	2	1.81	
Above 25 dB	1	0.9	

Discussion:

The present study was conducted to know the awareness about hearing loss among the medical students who are using PADs and their effects on the hearing mechanism of their ears; to evaluate the audiological function of these students with the help of pure tone audiometry.

Out of 463 students who received the questionnaires only 110 (23.75%) participated and were matching with the inclusion and exclusion criteria. The mean age was 22.30±2.45 years. Among the 110 students 48 (43.63%) were aged between 18 and 21 years, 62 (60%) were aged 22 to 25 years. 71 (64.54%) students were females and 39 (35.45%) were males with a male to female ratio of 1:1.82. The mean age was similar to few studies in the literature. [19]Basu S, Garg S, Singh MM et al (20) from their study reported 233 (60.1%) male and 155 (39.9%) female students.

The number of female students in medical colleges in India is increasing in similarity with the other countries (19, 21) Demographic details like smoking and family history of HL in early age were observed with smoking habit in 19 (17.27%) students. A family history of hearing loss (HL) was present in 11 (10%) students. (Table 1) Urban students were more than the rural students 67 (60.90%) and 43 (39.09%) respectively.

ZhuangJianga, BotaoFa et al [22] reported the worse W-HL group had risk factors in demographic data such as old age, longer career length, larger average cumulative noise exposure dose, family history and a higher proportion of male workers, smokers, and drinkers, all differences were statistically significant at $p < 0.01$.

In this study there was no hearing loss in 102 (92.72%) of the students, mild hearing loss in 05 (04.54%), moderate in 02 (01.81%) and severe in 01 (0.90%) students. (Table 2) In a study by Basu S, Garg S, Singh MM et al [20] self-reported history of HL was seen with tinnitus among 10.6%

and 6.4%, respectively which for at least 3 days in the previous 6 months. In comparison from a from USA college, authors reported hearing loss and tinnitus among 11.2% and 15.9% of the students, respectively. (23) Experiencing transient tinnitus in students might be an indication of starting of HL. [24] These students had not undergone any audiological tests in the previous 05 years. So the diagnosis might have been missed when the HL was in the mild form. Hence periodic audiological examination should be advised by the health personnel in students using PADs.

In this study 71 (64.54%) students were using PADs, 12 (10.90%) were using external PAD, car PAD was used by 22 (20%), (Table 4) 64 (58.18%) students were using PADs for less than 03 hours, 31 (28.18%) students were using between 03 and 05 hours and 15 (13.63%) students were using for 05 to 08 hours.

The volume of PAD used was less than 49% in 67 (60.90%) students, 50 to 69% in 39 (35.45%) students, 60 to 69% in 10 (03.09%) students and above 70% in 04 (03.63%) students (Table 4). In the study by Basu S, Garg S, Singh MM et al (20) 93.6% students were using smartphones. 52.8% of student's headphones for listening to music on their PADs, 34% of students used ear buds, 08.8% of students used canal-type earphones, 02.8% of students used noise-canceling earphones, and 01% used Bluetooth headsets. 45.6% students had used PADs for >5 years, 35.3% students had used between 2 and 5 years, and 18.8% students had used <2 years.

Age correlated with duration of PAD usage ($P < 0.01$). It suggested that they had developed the habit of using PADs during their middle-to-late adolescence which continued into adulthood. In their study the 68.34% of students used PADs for more than 5 days in a week and male students were 47.93% among them. The duration of PADs usage was similar to the present study. Majority of the students (56.2%) used their PADs for music at

23.6% at loud volume, 12.6% at somewhat loud and 20.1% at very loud volume. The questionnaire survey showed that 20.5% of their students felt that HL was unlikely due to use of PADs and 24.5% of students felt that ringing sensation was unlikely due to PADs usage.

In the present study 11.81% of the students opined that a temporary shift in threshold levels of hearing would occur due to usage of PADs. 12.72% of students felt that it would produce permanent threshold shifts. 35.45% of the students felt that NIHL could be prevented by minimizing the PADs usage.

In the present study 03 (02.72%) students had their air, bone conduction thresholds, a-b gap and PTA more than 25dB in the study. (Table 5) This study was similar to a study by Hoover A, Krishnamurti S et al [23] reported from California among the USA students that there were very few students with HL more than 25dB.

Few studies observed that HL in teenagers and young adults as a result of Noise induced mechanism especially in higher frequencies [25] Other studies did not find such conclusions [26, 27] Similar to the present study many studies used the Air conduction, bone conduction notches and PTA values with a clear cut clinical history to diagnose HL in their students. [28]Asghar S, Khan H, Parveen S et al [29] observed that the PTA values of 1/3rd of their subjects (medical students had mild sensorineural hearing loss at lower frequencies (250 Hz and 500 Hz).

Similar pattern of low frequency hearing loss was also detected in a study conducted among 56 medical students. [30] It was observed that the awareness about NIHL was present in 60 to 75% of the medical students in this study. 25 to 30% of the students were not aware of the NIHL and its causes and effects.

The remaining 05 to 15% students were uncertain. (Table 3) In a similar study by Srihari A., Shanmukananda P et al [31] on 3000 students among whom 72% were aware of NIHL. 03.2% of the subjects were suffering from NIHL due to PADs. 50 % of the subjects reported that PADs were used 06 hours per day.

Among the subjects with NIHL headphone users were 81%, and they were using more than 60% volume setting. More than 65% of the students were using the PADs for more than 06 years. 09% of the students experienced vertigo and tinnitus.

Conclusions:

Medical Students frequently using PADs for music at different volumes possessed sufficient information about impending HL and other ill effects of Health. Students were identified to have

NIHL due to usage of PADs. Awareness about ill effects of PADs and road safety were possessed by majority of the students. Use of objective methods of hearing assessment should be undertaken to identify NIHL at the earliest in those who used PADs.

References:

1. World Health Organization Hearing Loss Due to Recreational Exposure to Loud Sounds: A Review. Geneva: World Health Organization; 2015.
2. Poushter J. Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies. Pew Research Center's Global Attitudes Project. 2016. Feb, [Last accessed on 2018 Jan 07]. Available from: <http://www.pewglobal.org/2016/02/22/smartphone-ownership-and-internet-usage-continues-to-climb-in-emerging-economies/>
3. Fligor BJ, Cox LC. Output levels of commercially available portable compact disc players and the potential risk to hearing. *Ear Hear.* 2004; 25:513–27. [PubMed] [Google Scholar]
4. Williams W. Noise exposure levels from personal stereo use. *Int J Audiol.* 2005; 44:231–6.
5. Occupational Noise Exposure: Revised Criteria. Ohio: US Department of Health and Human Services; 1998. US Department of Health and Human Services.
6. R.J. Kamil, F.R. Lin. The effects of hearing impairment in older adults on communication partners: a systematic review *J. Am. Acad. Audiol.*, 2015;26(2): 155-182.
7. P. Mick, I. Kawachi, F.R. Lin. The association between hearing loss and social isolation in older adults *Otolaryngology*, (2014;150(3): 378-384.
8. Zia S, Akram U, Ali SA, Bokhari H, Naim M, Oza F, et al. Relationship of Ear Phone Usage and Recreational Noise Induced Hearing Loss Based on Audiogram Assessment. *J Liaquat Uni Med Health Sci.* 2016;15(4):191–198.
9. Watkinson John C. Psychoacoustic audiometry. 8th ed. CRC Press; 2018. Scott-Brown's Otorhinolaryngology: Head and Neck Surgery. In: Clarke, Ray W, editors; 2018; 629–641.
10. W. Han, J. O. Shin, J. H. Ma et al., "Distinct roles of stereociliary links in the nonlinear sound processing and noise resistance of cochlear outer hair cells," *Proceedings of the National Academy of Sciences of the United States of America*, 2020; 117(20): 11109–11117.
11. "Noise and hearing loss," *Lancet* (London, England), 1991; 338:8758: 21-22.
12. The Cochrane Collaboration, E. Kateman, J. H. Verbeek et al., "Interventions to prevent occupational noise induced hearing loss," *The*

- Cochrane Database of Systematic Reviews, 2017;7.
13. The Cochrane Collaboration, J. H. Verbeek, E. Kateman, T. C. Morata, W. Dreschler, and B. Sorgdrager, "Interventions to prevent occupational noise induced hearing loss," The Cochrane Database of Systematic Reviews, 2009; 3.
 14. E. Lynch and J. Kil, "Compounds for the prevention and treatment of noise-induced hearing loss," *Drug Discovery Today*, 2005; 10(19): 1291–1298.
 15. G. Harding, B. Bohne, and M. Ahmad, "DPO-AE level shifts and ABR threshold shifts compared to detailed analysis of histopathological damage from noise," *Hearing Research*, 2002; 174(1-2): 158–171.
 16. M. Liberman, "Noise-induced hearing loss: permanent versus temporary threshold shifts and the effects of hair cell versus neuronal degeneration," *Advances in Experimental Medicine and Biology*, 2016; 875: 1–7.
 17. Theodoroff SM, Lewis MS, Folmer RL, Henry JA, Carlson KF, Hearing impairment and tinnitus: prevalence, risk factors, and outcomes in US service members and veterans deployed to the Iraq and Afghanistan wars. *Epidemiol. Rev.* 2015; 37:71–85.
 18. Peng JH, Tao ZZ, Huang ZW. Risk of damage to hearing from personal listening devices in young adults. *J Otolaryngol.* 2007; 36(3):181–185.
 19. Basu S, Garg S, Singh MM, Kohli C. Knowledge and practices related to the use of personal audio devices and associated health risks among medical students in Delhi. *J Educ Health Promot.* 2019 Feb 15; 8:42.
 20. Kashyap P, Bhatia A. Effect of Duration of Exposure to Personal Listening Devices on Hearing Thresholds in Young Adults. *Ind J Otolaryngol and Head Neck Surg.* 2018; 70(4):583–586.
 21. Zhuang Jianga, Botao F, Xunmiao Zhange, Jiping Wanga, Yanmei Fenga, Haibo Shi, Yue Zhang, Daoyuan Sune, Hui Wanga, Shankai Yina. Identifying genetic risk variants associated with noise-induced hearing loss based on a novel strategy for evaluating individual susceptibility; <https://doi.org/10.1016/j.heares.2021.108281>.
 22. Hoover A, Krishnamurti S. Survey of college students' MP3 listening: Habits, safety issues, attitudes, and education. *Am J Audiol.* 2010; 19:73–83.
 23. Ansari H, Mohammadpoorasl A, Rostami F, Maleki A, Sahebihagh MH, Naieni KH, et al. Pattern of use of earphone and music player devices among Iranian adolescents. *Int J Prev Med.* 2014; 5:776–81.
 24. Montgomery JK, Fujikawa S. Hearing thresholds of students in the second, eighth, and twelfth grades. *Lang Speech Hear Serv Sch.* 1992; 23:61–3.
 25. Persson BO, Svedberg A, Göthe C-J. Longitudinal changes in hearing ability among Swedish conscripts. *Scand Audiol.* 1993; 22:141–3.
 26. Rabinowitz PM, Slade MD, Galusha D, Dixon-Ernst C, Cullen MR. Trends in the prevalence of hearing loss among young adults entering an industrial workforce 1985 to 2004. *Ear Hear.* 2006; 27:369–75.
 27. Schlauch RS, Carney E. The challenge of detecting minimal hearing loss in audiometric surveys. *Am J Audiol.* 2012; 21:106–19.
 28. Asghar S, Khan H, Parveen S, Rafi ST. Frequency of hearing loss among medical students using electroacoustic device. *Pak J Med Sci.* 2022 Mar-Apr; 38(3Part-I):668-673.
 29. Zia S, Akram U, Ali SA, Bokhari H, Naim M, Oza F, et al. Relationship of Ear Phone Usage and Recreational Noise Induced Hearing Loss Based on Audiogram Assessment. *J Liaquat Uni Med Health Sci.* 2016; 15(4):191–198.
 30. Srihari A., Shanmukananda P., Kumar L.S.D., John S. Analysis of potential risk of hearing loss among students using personal audio devices. *Natl. J. Physiol. Pharm. Pharmacol.* 2021; 11(5):462–465.