ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

DOI: 10.24179/kbbbbc.2024-105264

# Evaluation of Peripheral Hearing and Balance Function of Construction Workers Working in Noisy Environment

## Gürültülü Ortamda Çalışan İnşaat İşçilerinin Periferik İşitme ve Denge Fonksiyonunun Değerlendirilmesi

Tuğçe Gül ÇAĞLAR[a], Berna Deniz KUNTMAN[b], Hatice Seyra ERBEK[c]

[a]Lokman Hekim University Faculty of Health Sciences, Department of Audiology, Ankara, Türkiye
[b]University of Health Sciences Gülhane Faculty of Health Sciences, Department of Audiology, Ankara, Türkiye
[c]Lokman Hekim University Faculty of Health Sciences, Department of Otorhinolaryngology, Head and Neck Surgery, Ankara, Türkiye

**ABSTRACT Objective:** Noise-induced hearing loss is most prevalent problem in industrial audiology. In this study, construction employees who had spent at least five years in the industry and worked in a noisy setting had their peripheral hearing and balance systems assessed. **Material and Methods:** The study included 34 construction workers and 30 healthy volunteers. The following tests were applied to the participants for evaluation: pure tone audiometry, high-frequency audiometry, speech tests, speech audiometry and acoustic immitancemetry. Each participant underwent the Video Head Impulse Test (vHIT), Videonystagmography (VNG) and positional tests to assess their balance system. **Results:** The control group (n=30), 28-males and 2-females participated, and all males participated in the study group. A decrease in hearing threshold was observed in personnel working in noisy environments after 4000 Hz. "Acoustic notch" was observed in the entire study group (30/34). This was not observed in the control group. When pure tone averages were compared, statistically significant difference was found between the study group and the control group ($p<0.001$). In high frequency audiometry, a statistically significant difference was found between the study groups at 10000-12000-14000-16000 Hz. In the VNG test (pursuit-optokinetic-saccade tests), a significant gain-loss was found in the study group compared to the control group ($p<0.05$). No significant difference was found between the groups in vHIT ($p>0.05$). **Conclusion:** According to the results of our study, construction workers are susceptible to the development of noise-induced hearing loss. That is recommended to use the VNG test in the evaluation of the vestibular system of people working in noise.

**Keywords:** Construction workers; noise; hearing loss; vestibular system; audiology

**ÖZET Amaç:** karşılaşılan sorundur. Bu çalışmada sektörde en az beş yıl çalışmış ve gürültülü ortamda çalışan inşaat çalışanlarının periferik işitme ve denge sistemleri değerlendirildi. **Gereç ve Yöntemler:** Çalışmaya 34 inşaat işçisi ve 30 sağlıklı gönüllü dahil edildi. Her katılımcıya değerlendirme için uygulanılan testler: saf ses odyometrisi, yüksek frekanslı odyometri, konuşma testleri konuşma odyometrisi ve akustik immitansmetri. Her katılımcıya denge sistemlerini değerlendirmek için Video Baş İmpulsu Testi (vHIT), Videonistagmografi (VNG) ve pozisyonel testler uygulanmıştır. **Bulgular:** Çalışma grubunun tamamı erkekti. Kontrol grubunda (n:30) ise 28 erkek ve 2 kadın gönüllü çalışmaya dahil edildi. Gürültülü bir ortamda çalışan personelde 4000 Hz'den sonra işitme eşiğinde bir azalma gözlendi. Çalışma grubunun çoğunluğunda (30/34) "akustik çentik" gözlemlendi. Kontrol grubunda ise yüksek frekanslara doğru bir kayıp gözlenmedi. Saf ton ortalamaları karşılaştırıldığında, çalışma grubu ile kontrol grubu arasında istatistiksel bir fark tespit edildi ($p <0,001$). Yüksek frekanslı odyometride, çalışma grupları arasında 10.000-12.000- 14.000-16.000 Hz'de istatistiksel olarak anlamlı bir fark vardı. VNG test bataryasında (pursuit, optokinetic ve sakkad testlerinde), çalışma grubun ile control grubu karşılaştırıldığında anlamlı bir kazanç kaybı vardı ($p <0,05$). vHIT'de gruplar arasında anlamlı bir fark bulunamadı ($p>0,05$). **Sonuç:** Çalışmamızın sonuçlarına göre inşaat işçileri gürültüye bağlı işitme kaybı gelişimine duyarlıdır. Gürültüde çalışan kişilerin, vestibüler sisteminin değerlendirmesin de VNG testi kullanılması önerilmektedir.

**Anahtar Kelimeler:** İnşaat işçileri; gürültü; işitme kaybı; vestibüler sistem; odyoloji



**Correspondence:** Tuğçe Gül ÇAĞLAR
Lokman Hekim University Faculty of Health Sciences, Department of Audiology, Ankara, Türkiye
**E-mail:** tugcegulcaglar@gmail.com

Peer review under responsibility of Journal of Ear Nose Throat and Head Neck Surgery.

***Received:*** 26 Aug 2024 ***Received in revised form:*** 19 Nov 2024 ***Accepted:*** 19 Nov 2024 ***Available online***: 04 Dec 2024

Noise is becoming more common in industrial society.[1] Noise is expressed as an unwanted and disturbing sound. It is known that as the exposure time to noise increases, there are permanent or temporary changes in the structure and function of the hearing system. These changes may include hearing loss or disturbances in the balance system. Studies on this subject, noise-induced hearing loss (NIHL) is the second most common cause of sensorineural hearing loss.[2]

In the ear affected by noise, not only hearing but also the balance system is adversely affected. Although there are occupational noise standards to protect the hearing sensitivity of the workers, the hearing system continues to be adversely affected due to the loud noise they are exposed to in the work areas.[1]

The role of balance systems is to provide accurate information about our position in space and the direction and speed of our movement. In addition, it prevents falling by quickly correcting the changes that may occur in body position due to gravity. Also, the balance system functions to control eye movement to maintain gaze stabilization during movement. Our ability to maintain balance is related to our systems working together with every movement of our body.[3]

Construction sites are areas where there is loud noise and continuous noise. Many people can spot the presence of construction at the beginning of a street from their home. According to the "Health Surveillance Guide in Working Life" published by the Ministry of Labor and Social Security, NIHL is one of the most frequently observed occupational diseases in construction workers. Because the daily noise level in general at construction sites is above 80 dB.[4]

Permanent hearing loss is common as a result of noise exposure. The intensity, duration and intensity of the sound affect the resulting hearing loss. It is known that as the duration of noise exposure increases, there are permanent or temporary changes in the structure and function of the auditory system. These changes may include hearing loss or disturbances in the balance system. Permanent hearing loss is common as a result of noise exposure. Exposure to noise affects not only the cochlea but also the neurodegenerative structure.[5]

In the previous studies, NIHL was evaluated by the acoustic notch on the audiogram. In our study, a specific occupational group determined to work in a noisy environment was selected and evaluated. The purpose of selecting construction workers working in noisy environments is that there is no previous study that includes audiovestibular evaluation and there is high noise in construction sites in general.

The aim of this study was to examine the peripheral hearing and balance systems of construction workers working in noisy environments with pure tone audiometry pure tone audiometry, high frequency audiometry, speech tests speech audiometry, and acoustic immitancemetry, videonystagmography (VNG) and Video Head Impulse Test (vHIT) tests.

## MATERIAL AND METHODS

34 construction workers and 30 healthy volunteers who volunteered to participate in the study were examined by an otolaryngologist. This study was approved by the Başkent University Non-Interventional Clinical Researches Ethics Committee (date: March 30, 2022, no: KA22/128) and was supported by the Başkent University Research Fund. Hearing tests and then balance test batteries were applied to the participants who did not have any obstacles to perform the tests in the external auditory canal. Tests were performed in the Department of Otorhinolaryngology of Başkent University Ankara Hospital. The research was conducted between March and December 2022. External center tests are not included and participants who work more than five years are included in the evaluation. All procedures were carried out in accordance with the ethical principles of the Declaration of Helsinki.

Hearing and balance tests applied to all volunteers participating in the study are as follows; Pure Tone Audiometry, Speech Audiometry, High Frequency Audiometry, Acoustic Immitancemetry, VNG test battery (Horizontal Gaze Nystagmus Test, Vertical Gaze Nystagmus Test, Spontaneous Nystagmus Test, Pursuit Testing, Optokinetic Testing, Saccade Test, Dix-Hallpike Test, Supine Head-Roll Test), vHIT.

## PURE TONE AUDIOMETRY

Pure Tone Audiometry was performed with the Interacoustics-Clinical Audiometer AC-40 device in a quiet cabin in accordance with the "Industrial Acoustic Company" (IAC) standard. Air conduction hearing thresholds were tested using Telephonic TDH-39 headphones at frequencies between 125 and 8,000 Hz, and bone conduction hearing thresholds were tested using the Radioear B-71 bone vibrator at frequencies between 250-4,000 Hz. The inclusion criteria of healthy volunteers were those with normal hearing and a speech discrimination score of 92% and above, whose air conduction and bone conduction thresholds and pure tone averages were below 15 dB.

## HIGH FREQUENCY AUDIOMETRY

After attaching a special earphone for high frequencies, high frequency audiometry is performed by sending a signal at frequencies between 8,000 and 20,000 Hz. Tests were performed with the Interacoustics-Clinical Audiometer AC 40 device in a quiet cabin in accordance with the IAC standard. High frequency measurements were made using MX 41 headphones at frequencies between 10, 12, 14, 16 and 18 kHz. After pure tone audiometry test was done to all of the participants, high frequency test was applied.

## ACOUSTIC TYMPANOMETRY

The test was performed with the probe placed in the external ear canal of patients. Immitancemetric measurements were performed with the GSI Tympstar Version 2 (Grason Stadler Inc., MN, USA) electroacoustic immittance meter. Tympanogram recording was between -100 and +100 using a 226 Hz probe tone and included those with Type A tympanograms.

## VNG

VNG tests were recorded using Micromedical VisualEyes 4 Channel (Micromedical Technologies, IL, USA) VNG device and glasses. Participants were asked to follow the light bar, one meter away from where they were sitting, with only eye movements without moving their heads. After the calibration process was completed, all of the VNG test batteries (spontaneous nystagmus, gaze, pursuit, optokinetic, and saccade tests) were applied sequentially.[6]

## SUPIN ROLL TEST

The patient is placed on a stretcher on his back with a pillow (30 degrees) under his head with VNG goggles on. With this test, the patient's lateral semicircular canals are evaluated. The head is first turned 90 degrees to the right, then brought to the midline and waited, and finally the head is turned 90 degrees to the left again, recording for 1 minute separately for each position.

## DIX-HALLPIKE TEST

Dix-Hallpike Test was applied with VNG. During the test, the cover of the VNG glasses was closed and the patient was sitting, and the patient was kept on his back with his head hanging 30 degrees below the stretcher, and the recording was taken. The patient was then placed in a sitting position. After the waiting period, the patient who did not have a complaint of dizziness was placed on his back and the same test was repeated on the right side.

Dix-Hallpike test left lying (supine position), Dix-Hallpike test take off from the left (sitting position), Dix-Hallpike test lying to the right (supine position), In the Dix-Hallpike test, taking off from the right (sitting position), eye movements were provided with VNG.

## vHIT

vHIT was performed with the OTOsuite Vestibular (Software Version: 3.00 Build 1007, Otometrics) computer program and video camera mounted glasses (Type- 1085 ICS impulse). After the test was explained to the participant, glasses with a video camera were put on and they were seated at a distance of one meter from wall. During the test, he was asked to stand upright and look at the black dot opposite him. Calibration was performed initially for each patient. In the vHIT test, firstly the lateral test (lateral semicircular canals test), then the left anterior right posterior and right anterior left posterior canal tests were performed.[7] Vestibulo-ocular reflex (VOR) gain is the ratio of eye movement velocity to head movement velocity. VOR gains between 0.8 and 1.2 are considered normal for the lateral semicircular canals, while this ratio is between 0.7 and 1.2 for the vertical semicircular canals. Gains below these ratios are considered abnormal. The VOR is functional over a wide frequency spectrum from 0.001 Hz to 100 Hz, and vHIT allows testing the VOR at high frequencies.[7,8]

### STATISTICAL ANALYSIS

SPSS 26.0 (IBM, USA) package program was used in the statistical analysis of the data. In comparing continuous measurements between groups, distributions were checked and independent samples t-test was used for parameters with normal distribution, and Mann-Whitney U test was used for parameters that did not show normal distribution. Chi-square and Fisher's exact test were used to compare categorical variables. In all tests, the statistical significance level was taken as 0.05.

## RESULTS

### DEMOGRAPHIC INFORMATION

A total of 64 people enrolled in this study. Thirty-four of these participants were construction workers working in noisy environments, and there were 30 healthy volunteers in the control group. All of the construction workers were male participants, 28 of the healthy participants were male and 2 female participants were evaluated.

Workers in the study group were selected from those between the ages of 18-55 and who had worked at the construction site for at least five years. Workers with temporal bone fractures, recent surgery, and hearing loss were excluded. Individuals in the control group were selected from those who have never worked in a noisy environment, between the ages of 18-55, who have no hearing loss, and who have a normal eardrum in the ENT examination.

### AUDIOLOGICAL FINDINGS

Type A tympanogram was obtained in all participants. The difference between the study and control groups was compared in the threshold values of 0.25 kHz, 0.5 kHz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz in both the right and left ears of the participants. Analysis results are given in Table 1.

The differences in pure tone audiometry averages, speech reception thresholds and speech discrimination scores between the groups are statistically significant. Accordingly, the parameter mean of the experimental group was significantly higher than the control group (p<0.001).

The distribution of high frequency hearing thresholds in both groups is as in Table 2. In the high frequency audiometry, the values at 10,000-12,000-14,000-16,000 and 18,000 Hz were compared.

The differences between the groups at all frequencies, except for the 18,000 Hz, are statistically significant. Accordingly, the parameter mean of the experimental group was significantly higher than the control group (p<0.001).

### VESTIBULAR TESTS FINDINGS

In both the study group and the control group, nystagmus was not observed in the Horizontal Gaze, Vertical Gaze, Spontaneous Nystagmus, Saccade and Supine head roll test. Gain loss was observed in the

**TABLE 1:** Intergroup comparison pure tone audiology right, pure tone audiology left, speech comprehension threshold and speech distinguishing.

| | Group | N | $\bar{X}$±SD | U | p value |
|---|---|---|---|---|---|
| Pure Tone Audiology Right[a] | Subject | 34 | 24.21±13.165 | 78.5 | **<0.001*** |
| | Control | 30 | 8.93±3.732 | | |
| Pure Tone Audiology Left[a] | Subject | 34 | 16.78±9.692 | 91 | **<0.001*** |
| | Control | 30 | 9.23±5.191 | | |
| Speech Comprehension Threshould Test[b] | Subject | 34 | 28.53±27.56 | 3.86 | **<0.001*** |
| | Control | 30 | 10.00±4.57 | | |
| Speech Distinguishing Test[b] | Subject | 34 | 87.24±18.916 | -2.490 | **0.017** |
| | Control | 30 | 95.87±6.68 | | |

[a]Mann-Whitney U testi; [b]Independent samples t-test; *p<0.001; SD: Standard deviation.

**TABLE 2:** Comparison of high frequency hearing thresholds between two groups.

| | Group | N | $\bar{X}$±SD | U | p value |
|---|---|---|---|---|---|
| R 10000[b]Hz | Subject | 30 | 51.17±20.20 | 6.504 | **<0.001*** |
| | Control | 30 | 23.50±11.60 | | |
| R 12000[b]Hz | Subject | 27 | 59.26±24.32 | 6.091 | **<0.001*** |
| | Control | 30 | 26.00±15.39 | | |
| R 14000[b]Hz | Subject | 17 | 54.41±18.53 | 5.612 | **<0.001*** |
| | Control | 30 | 26.00±15.55 | | |
| R 16000[b]Hz | Subject | 13 | 49.23±13.82 | 4.110 | **<0.001*** |
| | Control | 30 | 28.17±16.05 | | |
| R18000[b]Hz | Subject | 11 | 29.09±6.64 | 0.144 | 0.887 |
| | Control | 30 | 28.63±13.57 | | |
| I.10000[b]Hz | Subject | 30 | 53.00±21.56 | 6.206 | **<0.001*** |
| | Control | 30 | 24.50±12.95 | | |
| I.12000[b]Hz | Subject | 25 | 59.20±26.68 | 5.454 | **<0.001*** |
| | Control | 30 | 26.00±16.04 | | |
| I.14000[b]Hz | Subject | 15 | 48.00±20.07 | 3.920 | **<0.001*** |
| | Control | 30 | 26.33±16.07 | | |
| I.16000[b]Hz | Subject | 11 | 44.09±22.34 | 2.454 | **0.019** |
| | Control | 30 | 28.17±116.84 | | |
| I.18000[b]Hz | Subject | 9 | 29.44±6.82 | -0.221 | 0.827 |
| | Control | 30 | 30.17±12.89 | | |

[a]Mann-Whitney U testi; [b]Independent samples t-test; *p<0.001.



Pursuit and Optokinetic tests in the VNG test battery. Dix-Hallpike nystagmus was present in the study, and the differences between the pursuit and optokinetic gain loss parameters were statistically significant compared to the experimental and control groups (p<0.001) (Table 3).

In the vHIT test, no significant difference in gain was found between the groups (p>0.05). One patient in the study group had overt saccade and covert saccade. No nystagmus was observed in the VNG and positional tests of this patient.

**TABLE 3:** Intergroup comparison Dix-Hallpike, Pursuit and Optokinetic tests.

| | Subject n% | Control n% | p value |
|---|---|---|---|
| Dix-Hallpike Right[c] | 27 (47.40) | 30 (52.60) | **0.012*** |
| | 7 (100) | 0 | |
| Pursuit[c] | 28 (48.3) | 30 (51.70) | **0.026*** |
| | 6 (100) | 0 | |
| Opkokinetic[c] | 24 (46.20) | 28 (53.80) | **0,026*** |
| | 10 (83.30) | 2 (16.70) | |

[c]Fishers exact test; *p<0.05; SD: Standard deviation.

## DISCUSSION

Many etiologies of sensorineural hearing loss are known. Among these, the most common age-related hearing loss (presbycusis), genetic or environmental factors, exposure to noise and side effects of ototoxic drugs.[9,10] Other etiologies include autoimmune disorder, head trauma, and hair cell overstimulation.[11,12]

Stereocilia located on the surface of hair cells are very susceptible to mechanical damage. Direct exposure of stereocilia to noise causes mechanical deterioration and changes the normal cellular structure of the organ of Corti.[13,14] Changes that may occur in the organ of Corti and hair cells cause permanent results in the hearing and balance system. In this study, both the peripheral hearing system and the vestibular system of construction workers working in a noisy environment are evaluated. There are many studies on NIHL. Our study examines the vestibular system in people with NIHL.

VNG and vHIT tests were applied to evaluate the participants' vestibular system. Both tests are widely used without evaluating the vestibular system. Bayat et al. showed in their study that there is hypersensitivity in the vestibular system in patients exposed to chronic noise with VNG and cervical vestibular myogenic potential tests.[15] Elewa et al., patients with chronic noise exposure vHIT test findings were examined. As a result of this study unlike our study there was a statistically significant difference in vHIT lateral canal gain between the study and control groups. A statistically significant negative correlation between duration of noise exposure and lateral canal gain was also present.[16]

In NIHL, there is often symmetrical sensorineural hearing loss in both ears. Sometimes, if exposed to one-sided noise, for example, asymmetrical, unilateral hearing loss may occur due to gunshot or loudspeaker direction.[17] The results of pure tone audiometry in the workers participating in our study were generally symmetrical and sensorineural type hearing loss, which is similar to the literature. Individuals participating in this study did not use ear protection.

According to the study conducted by McBride and Williams in 2001, it was stated that individuals with NIHL had hearing loss that started after 2 kHz and affected 3, 4, and 6 kHz, and notches were observed at these frequencies.[18] In another study conducted in 2012, it was stated that there should be a notch at 4 or 6 kHz for NIHL.[19] In our study, a decrease in hearing thresholds was observed in 28 out of 34 construction workers after 4000 Hz. Our study is also compatible with the studies published before us. Nada et al. conducted a study of 145 textile workers with a statistically significant difference in the hearing loss of workers working in noisy environments compared to the control group.[20]

The health of employees working in noisy environments such as construction sites, carpentry workshops, shipyards and factories must be regularly monitored, and the necessary precautions must be taken. Employee precautions such as earplugs, personal protective equipment or earplugs should be taken to reduce exposure to noise. If the machine is the source of noise, it should be tried to reduce the decibel of the noise by using sound curtains or sound barriers.

We think that our study will be a source of audiological data on NIHL in the scientific field. There are limited studies investigating the effects of noise on the long-term auditory system. We didn't evaluate retrocochlear function we didn't use the electrophysiological method. Unfortunately, occupational discrimination is not made in demographic information in these studies, generally on NIHL. The study was carried out during the pandemic period, hence a larger sample size was not possible. In this regard, more studies on occupational diseases can provide useful information in determining the levels and effects of IHL.

## CONCLUSION

According to the results of this study, noise may have an effect on the hearing and balance system. In addition, our study has been a pioneer study for research on this subject. Periodic ear examinations and hearing tests should be performed, and health surveillance should be carried out for the employees in the work areas with a noise level of more than 80 dB. In addition to peripheral hearing, studies should be carried out with objective and subjective methods that evaluate central auditory pathways and efferent hearing systems. That is recommended to use tests that evaluate the vestibular system, such as the VNG test, in the evaluation of the vestibular system of people working in noise.

***Source of Finance***

*This study was approved way Başkent University Institutional Review Board (Project no: K22/128) and supported by Başkent University Research Fund.*

***Conflict of Interest***

*No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.*

***Authorship Contributions***

***Idea/Concept:*** *Hatice Seyra Erbek, Tuğçe Gül Çağlar;* ***Design:*** *Hatice Seyra Erbek, Tuğçe Gül Çağlar;* ***Control/Supervision:*** *Hatice Seyra Erbek, Tuğçe Gül Çağlar;* ***Data Collection and/or Processing:*** *Hatice Seyra Erbek, Tuğçe Gül Çağlar;* ***Analysis and/or Interpretation:*** *Tuğçe Gül Çağlar;* ***Literature Review:*** *Tuğçe Gül Çağlar;* ***Writing the Article:*** *Tuğçe Gül Çağlar, Berna Deniz Kuntman;* ***Critical Review:*** *Hatice Seyra Erbek;* ***References and Fundings:*** *Hatice Seyra Erbek, Tuğçe Gül Çağlar;* ***Materials:*** *Tuğçe Gül Çağlar.*

## REFERENCES


1. Eggermont JJ. Noise and the Brain: Experience Dependent Developmental and Adult Plasticity. Noise and the Brain: Experience Dependent Developmental and Adult Plasticity. 1st ed. London: Academic Press; 2013.
2. Azizi MH. Occupational noise-induced hearing loss. Int J Occup Environ Med. 2010;1(3):116-23. PMID: 23022797.
3. Stach BA. The nature of hearing. Clinical Audiology. 2nd ed. Delmar: Cengage Learning; 2010. p.55-99.
4. Çalışma ve Sosyal Güvenlik Bakanlığı. Çalışma Yaşamında Sağlık Gözetimi Rehberi. Ankara; 2021. https://www.csgb.gov.tr/medias/4591/rehber03.pdf
5. Chen KH, Su SB, Chen KT. An overview of occupational noise-induced hearing loss among workers: epidemiology, pathogenesis, and preventive measures. Environ Health Prev Med. 2020;25(1):65. PMID: 33129267; PMCID: PMC7603754.
6. Huh YE, Kim JS. Bedside evaluation of dizzy patients. J Clin Neurol. 2013;9(4):203-13. PMID: 24285961; PMCID: PMC3840130.
7. Alhabib SF, Saliba I. Video head impulse test: a review of the literature. Eur Arch Otorhinolaryngol. 2017;274(3):1215-22. PMID: 27328962.
8. Bell SL, Barker F, Heselton H, MacKenzie E, Dewhurst D, Sanderson A. A study of the relationship between the video head impulse test and air calorics. Eur Arch Otorhinolaryngol. 2015;272(5):1287-94. PMID: 25416853.
9. McHaney VA, Thibadoux G, Hayes FA, Green AA. Hearing loss in children receiving cisplatin chemotherapy. J Pediatr. 1983;102(2):314-7. PMID: 6681630.
10. Cunningham LL, Tucci DL. Hearing loss in adults. N Engl J Med. 2017;377(25):2465-73. PMID: 29262274; PMCID: PMC6457651.
11. Mittal R, Lisi CV, Gerring R, Mittal J, Mathee K, Narasimhan G, et al. Current concepts in the pathogenesis and treatment of chronic suppurative otitis media. J Med Microbiol. 2015;64(10):1103-16. PMID: 26248613; PMCID: PMC4835974.
12. Ben Said M, Grati M, Ishimoto T, Zou B, Chakchouk I, Ma Q, et al. A mutation in SLC22A4 encoding an organic cation transporter expressed in the cochlea strial endothelium causes human recessive non-syndromic hearing loss DFNB60. Hum Genet. 2016;135(5):513-24. PMID: 27023905; PMCID: PMC4836961.
13. Liberman MC, Beil DG. Hair cell condition and auditory nerve response in normal and noise-damaged cochleas. Acta Otolaryngol. 1979;88(3-4):161-76. PMID: 495068.
14. Patuzzi RB, Yates GK, Johnstone BM. Outer hair cell receptor current and sensorineural hearing loss. Hear Res. 1989;42(1):47-72. PMID: 2684949.
15. Bayat A, Jafarzadeh S, Saki N, Omidvar S, Pourbakht A. Vestibular hypersensitivity in patients with chronic noise exposure. Indian J Otolaryngol Head Neck Surg. 2022;74(Suppl 3):3957-64. PMID: 36742751; PMCID: PMC9895205.
16. Elewa M, Nada E, Elnabtity N. Video head ımpulse test findings in patients with chronic noise exposure. Egyptian Journal of Ear, Nose, Throat and Allied Sciences. 2022;23(23):1-7. https://ejentas.journals.ekb.eg/article_231816_6d1438aea2944cacaf88b501069eaa37.pdf
17. Lajoie Y, Teasdale N, Bard C, Fleury M. Attentional demands for static and dynamic equilibrium. Exp Brain Res. 1993;97(1):139-44. PMID: 8131825.
18. McBride DI, Williams S. Audiometric notch as a sign of noise induced hearing loss. Occup Environ Med. 2001;58(1):46-51. PMID: 11119634; PMCID: PMC1740031.
19. Sliwinska-Kowalska M, Davis A. Noise-induced hearing loss. Noise Health. 2012;14(61):274-80. PMID: 23257577.
20. Nada E, Ebraheem M, Sheta S. Noise-induced hearing loss among workers in textile factory. Egypt J Otolaryngol. 2014;30:243-8. https://ejo.springeropen.com/articles/10.4103/1012-5574.138484