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Evaluation of Peripheral Hearing and Balance Function Among Construction Workers Working in Noisy Environments

Gürültülü Ortamlarda Çalışan İnşaat İşçilerinde 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 the 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. **Material and Methods:** This study included 34 construction workers and 30 healthy volunteers. The following tests were applied to the participants: 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:** In 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 effect was not observed in the control group. When pure tone averages were compared, a 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 with the control group (p<0.05). No significant difference was found between the groups in terms of vHIT (p>0.05). **Conclusion:** According to the results of our study, construction workers are susceptible to the development of noise-induced hearing loss. It is recommended to use the VNG test in the evaluation of the vestibular system of people working in noisy environments.

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

ÖZET Amaç: 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

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

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Noise is becoming more common in industrial society.[1] It is expressed as unwanted and disturbing sounds. As the exposure time to noise increases, permanent or temporary changes occur in the structure and function of the hearing system. These changes may include hearing loss or disturbance of the balance system. In previous studies on this subject, noise-induced hearing loss (NIHL) was found to be the second most common cause of sensorineural hearing loss.[2]

In the ear that is affected by noise, not only hearing but also the balance system is affected. Although there are occupational noise standards to protect the hearing sensitivity of 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 the balance system is to provide accurate information about the position and speed of our movement. In addition, it prevents falling by quickly correcting the changes that may occur in the body position due to gravity. The balance system also controls eye movement to maintain gaze stabilization during movement. Our ability to maintain balance is related to our systems, which work together with every movement of our body.[3]

Construction sites are areas where there is both loud and continuous noise. Many people can notice 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. The daily noise level at construction sites is generally above 80 dB.[4]

Permanent hearing loss is common because of exposure to noise. The intensity, duration, and intensity of the sound affect the resulting hearing loss. As the duration of noise exposure increases, permanent or temporary changes occur in the structure and function of the auditory system. These changes may include hearing loss or disturbance of the balance system. Permanent hearing loss is common because of exposure to noise. Exposure to noise affects not only the cochlea but also the neurodegenerative structure.[5]

In previous studies, the NIHL was evaluated by the acoustic notch on the audiogram. In this 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 no previous study has included audiovestibular evaluation, and there is generally high noise at construction sites.

The aim of this study was to examine the peripheral hearing and balance systems of construction workers working in noisy environments using pure tone audiometry, pure tone audiometry, high-frequency audiometry, speech tests, speech audiometry, acoustic immitancemetry, videonystagmography (VNG), and video head impulse test (vHIT) tests.

MATERIAL AND METHODS

Thirty four 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 Research Ethics Committee (date: March 30, 2022, no: KA22/128) and was supported by the Başkent University Research Fund. Hearing tests and balance test batteries were then applied to participants without any obstacles to performing the tests in the external auditory canal. The tests were performed in the Department of Otorhinolaryngology, Başkent University Ankara Hospital. The research was conducted between March and December 2022. External center tests were not included, and participants who worked more than five years were included in the evaluation. All procedures were conducted 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 using the Interacoustics-Clinical Audiometer AC-40 device in a quiet cabin in accordance with the "Industrial Acoustic Company" (IAC) standard. Air- and bone-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 and 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 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. The tests were performed using the Interacoustics-Clinical Audiometer AC 40 device in a quiet cabin in accordance with the IAC standard. High-frequency measurements were performed using MX 41 headphones at frequencies between 10, 12, 14, 16, and 18 kHz. After the pure tone audiometry test was performed for all participants, a high-frequency test was applied.

ACOUSTIC TYMPANOMETRY

The test was performed using a probe placed in the external ear canal. Immitancemetric measurements were performed using a 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 a 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 VNG test batteries (spontaneous nystagmus, gaze, pursuit, optokinetic, and saccade tests) were sequentially applied.[6]

SUPIN ROLL TEST

The patient is placed on a stretcher on his back with a pillow (30 degrees) under his head, and VNG goggles are placed. In 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. Finally, the head is turned 90 degrees to the left again, recording for 1 min for each position.

DIX-HALLPIKE TEST

The Dix-Hallpike test was performed with VNG. During the test, the cover of the VNG glasses was closed and the patient was sitting. The patient was kept on his back with his head hanging 30° below the stretcher, and the recording was recorded. The patient was then placed in a sitting position. After the waiting period, the patient who did not complain 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 using 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 placed on, and they were seated at a distance of 1 meter from the wall. During the test, he was asked to stand upright and look at the black dot in front of him. Calibration was initially performed for each patient. In the vHIT test, first, the lateral test (lateral semicircular canals test) and 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, whereas 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 (0.001-100 Hz), and vHIT allows testing the VOR at high frequencies.[7,8]

STATISTICAL ANALYSIS

The SPSS 26.0 (IBM, USA) package program was used for the statistical analysis of the data. In comparing continuous measurements between groups, distributions were checked, and the 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. The chi-squared test and Fisher's exact test were used to compare categorical variables. The statistical significance level in all tests was set at 0.05.

RESULTS

DEMOGRAPHIC INFORMATION

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

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

AUDIOLOGICAL FINDINGS

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

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

The distribution of high-frequency hearing thresholds in both groups is presented 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 18,000 Hz, were statistically significant. Accordingly, the parameter mean of the experimental group was significantly higher than that of the control group (p<0.001).

VESTIBULAR TESTS FINDINGS

In both the study and control groups, nystagmus was not observed in the horizontal gaze, vertical gaze, spontaneous nystagmus, saccade, and spinae head

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

	Group	N	X̄±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	X̄±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.

roll tests. Gain loss was observed in the 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 with the experimental and control groups (p<0.001) (Table 3).

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

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

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

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

The 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 hypersensitivity in the vestibular system in patients exposed to chronic noise with VNG and cervical vestibular myogenic potential tests.[15] Elewa et al. examined patients with chronic noise exposure vHIT test findings were examined. Because 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, 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 participants in our study were generally symmetrical and sensorineural type hearing loss, which is similar to the literature. The participants did not use ear protection.

According to a 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 previous studies. Nada et al. conducted a study on 145 textile workers and found a statistically significant difference in the hearing loss of workers working in noisy environments compared with 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 wearing earplugs, personal protective equipment, and earplugs should be taken to reduce exposure to noise. If the machine is the source of noise, it should be attempted to reduce the decibel level of the noise using sound drapes or sound barriers.

We believe that our study will provide a source of audiological data on NIHL in the scientific field. There are only few studies investigating the effects of noise on long-term auditory systems. We did not evaluate retrocochlear function and did not use the electrophysiological method. Unfortunately, occupational discrimination was not made in the demographic information of these studies, generally on NIHL. The study was conducted during the pandemic period; hence, a larger sample size was not possible. In this regard, more studies on occupational diseases can provide useful information for determining IHL levels and effects.

CONCLUSION

According to the results of this study, noise may affect hearing and balance. In addition, our study is a pioneering research on this subject. Periodic ear examinations and hearing tests should be performed, and health surveillance should be carried out for employees in work areas with noise levels exceeding 80 dB. In addition to peripheral hearing, studies should be conducted using objective and subjective methods to evaluate central auditory pathways and efferent hearing systems. It 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 noisy environments.

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.*

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