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Original Research

An Evaluation of the Vestibular System in Individuals Aged 40-65 Years with Sensorineural Hearing Loss

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Abstract

Objectives: Vestibular dysfunction occasionally accompanies sensorineural hearing loss (SNHL) due to anatomical proximity of cochlea and vestibule. The aim of the present study was to evaluate the vestibular system objectively and subjectively in 40-to 65-year-old individuals with and without SNHL.

Methods: This study included participants of both sexes, between the ages of 40 and 65 years old. There were 31 participants with SNHL and 31 control participants. First of all, participants were grouped in the control and SNHL groups based on the results of their hearing test, which included audiometry and immitance evaluation. Subsequently, for vestibular evaluation, each participant was evaluated subjective with "Dizziness Handicap Inventory" (DHI) as well as with objective tests battery that included positional tests with videonystagmogrophy (VNG) and vestibuloocular reflex (VOR) assessment using the vestibular head impulse test (vHIT).

Results: Peripheral nystagmus was found to be significantly higher in patients with SNHL based on the head shake and positional tests ($p<0.05$). There was a positive correlation between DHI scores and positional test findings of the participants with SNHL ($p<0.05$). When the VHIT VOR gain values were compared between groups, there was no significant difference ($p<0.05$).

Conclusion: In our study, vestibular involvement was frequently observed in 40- to 65-year-old individuals with SNHL. Therefore, vestibular evaluation should be considered along with the assessment of hearing in individuals with SNHL who are over 40 years old.

Keywords: Dizziness Handicap Inventory, sensorineural hearing loss, vestibular system

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According to the World Health Organization (WHO), hearing loss affects 6.1% of the world population and it is one of the most common sensory barriers.[1] In addition, it is one of the most common chronic diseases observed the older population. The most common type of hearing loss in this population is sensorineural hearing loss (SNHL).[2] Genetic predispositions, exposure to loud noise, or age-related pathological changes are often involved in the etiology.[3]

Although SNHL is caused by a pathology in any part of the auditory pathway from the cochlea to the brain, it is mostly associated with the damage of the sensory cells in the organ of Corti located in the inner ear.[4] Sensory cells do not have the required regenerative capacity to correct this damage. This damage can also affect the vestibular organs and thus cause many patients with age-related hearing loss to experience dizziness.[5] In other words, the question arises that cochlear dysfunction in patients with SNHL may

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cause vestibular deficit due to the anatomical and phylogenetic relationships of the cochlea and vestibular organs.[6]

The auditory and vestibular systems work together even though the mechanisms of interaction are not entirely clear. To date, studies analyzing the relationship between hearing loss and vestibular involvement in the general population are not sufficient. In addition, there are unclear points about the degree or type of hearing loss accompanying dizziness and vertigo.[7] Based on all these, we aimed to evaluate objectively and subjectively the vestibular system in 40- to 65-year-old individuals with or without SNHL.

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by Baskent University Institutional Review Board (Project no: KA20/307) and supported by Baskent University Research Fund. The study was conducted at the Audiology Unit, Department of Otorhinolaryngology, Baskent University Hospital Health Application and Research Center.

The study was designed and performed prospectively. This study consists of volunteers who applied to the Audiology unit of the Department of Otorhinolaryngology at Baskent University Hospital of Istanbul Health Application and Research Center. These volunteers are patients between the ages of 40-65 and the sex difference has been ignored. Informed consent was obtained from each individual to be included in the study. All volunteers were evaluated primarily with pure tone audiometry test, air-conduction and bone-conduction hearing thresholds, Speech Reception Threshold (SRT), Speech Discrimination (SD), Uncomfortable Loudness (UCL) and immitansmetric evaluation. Then they were grouped as normal hearing and sensorineural hearing loss. The tests included in the study were administered during the same visit. Initially, immitansmetric evaluations of the patient were performed. Then pure tone audiometry test, positional tests with VNG and finally VHIT were evaluated. After all tests were finished, DHI was administered by the clinician face to face with the patient. Participants were grouped into two groups: those with sensorineural hearing loss and those with normal hearing (control group). Some criteria have also been determined in order for the participants to be included in the study. Inclusion criteria of the participants in the case group, the presence of sensorineural hearing loss, no additional illness (hypertension, diabetes mellitus, etc.), no history of ototoxic drug use, no additional vestibular complaints such as dizziness, imbalance, not using hearing aid, without diagnosis disease and no history of head injury. Participants with bilateral moderate-to-severe hearing loss and age-related hearing loss were included in the case group. In this group, there were 12 mild, 12 moderate and 7 severe hearing loss in the right ear, and 9 mild, 15 moderate and 7 severe hearing loss in the left ear (Fig. 1 and Fig. 2). In the control group, there was no sensorineural hearing loss, no additional chronic disease, illness (hypertension, diabetes mellitus, etc.), no history of ototoxic drug use, no additional vestibular complaints such as dizziness and imbalance. Each participant was first evaluated for the middle ear by immitansmetric examination. Then, the type of hearing was determined by pure tone audiometry test. The data were grouped by taking into account the participant inclusion criteria. After dividing into groups, vestibular assessment was performed for each participant. In this study, all participants were assessed subjectively with the Dizziness Handicap Inventory (DHI) and a battery of objective tests, such as positional tests with VNG (videonystagmography) and vHIT (video head impulse test).

It is also known that the objective sign of vertigo is nystagmus. Peripheral or central cause of the pathology is determined according to the characteristics such as direction,

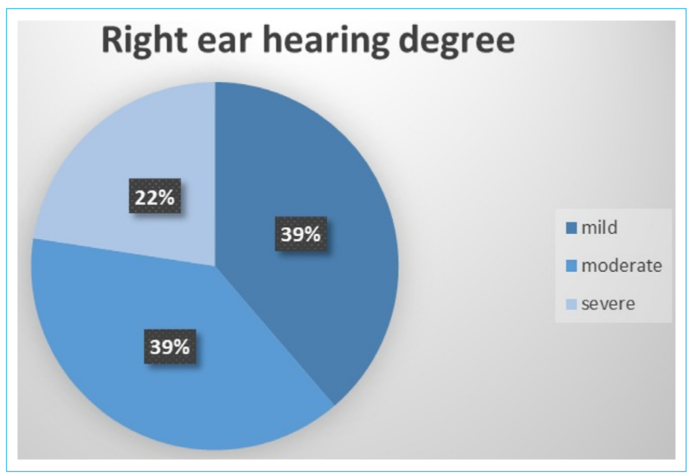

Figure 1. Case group right ear hearing loss degree.

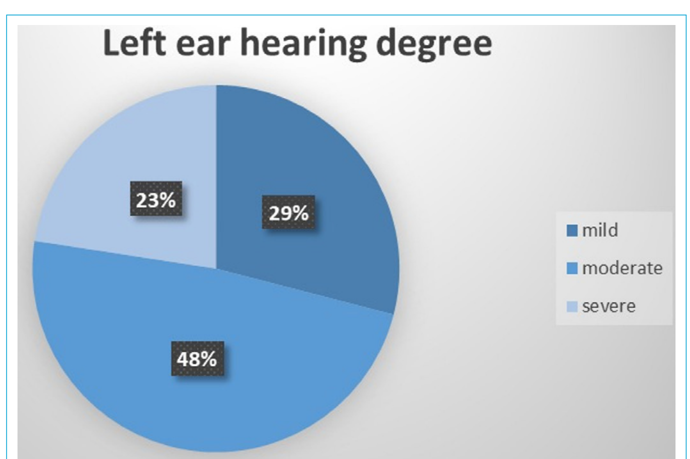

Figure 2. Case group left ear hearing loss degree.

duration and latency of nystagmus. According to the characteristics of nystagmus and the effect of visual fixation, peripheral and central nystagmus can be differentiated from many changes. In our study, the presence of peripheral nystagmus is studied. Peripheral nystagmus can be suppressed by fixation, horizontal-rotatory style, with its fast phase to the healthy side, tired over time, latency, short duration, unchanged direction. In our study, the nystagmus observed at the end of each test was evaluated in the light of these criteria.

A detailed anamnesis was taken from all participants included in the study. Then, middle ear pressure, compliance, and outer ear canal volume values were measured with a tympanometer (Interacoustics AT235, Denmark). Ipsilateral reflex and contralateral reflex thresholds were detected at frequencies of 500, 1000, 2000, and 4000 Hz. Subsequently, the air-conduction hearing thresholds of all individuals were obtained using an AC40 Interacoustics audiometer (Denmark) and TDH39 headphones between 125 and 8000 Hz, and the bone-conduction hearing thresholds were determined between 500 and 4000 Hz using a B71 bone vibrator. The volunteers are divided into groups according to the results.

Then, spontaneous nystagmus, headshake, and dynamic positional tests were performed using a Videonystagmography Biomed eVNG USB (Germany) device. In the spontaneous nystagmus test, the patient was asked to fixate straight ahead the eyes, and eye movements were recorded for 30 seconds. The recording continued for another 30 seconds after fixation was cancelled. In the headshake test, the patient's head was tilted 30 degrees forward while in sitting position to bring the lateral semicircular canals to the horizontal plane. The head was then shaken left and right with both hands for 20 seconds without interruption by the tester. Then, the patient's eye movements were recorded as in the spontaneous nystagmus test. And after the head was shaken to the right and left without interruption, the presence of peripheral nystagmus was investigated from eye movements. Peripheral nystagmus findings were determined as horizontal or torsional, unilateral direction, not changing with gaze direction, and suppression of nystagmus with visual fixation. The nystagmus observed after the head shake test was considered positive if these features matched, and negative if they did not.

In the Dix-Hallpike test for the right posterior semicircular canal, the patient's head was turned 45 degrees towards the right shoulder while sitting (in the Dix Hallpike test for the left posterior semicircular canal, the patient's head was turned 45 degrees towards the left shoulder). Then the patient was quickly placed on his back. When the patient was placed in the supine position, the patient's head was lowered 30 degrees from the horizontal plane. It was held in this position for about 30 seconds. The presence of vertigo was questioned, and the presence of nystagmus was observed simultaneously. If there is no vertigo or nystagmus, the patient is seated; Vertigo and nystagmus are observed by waiting for 30 seconds. The head was then turned to the left side and the same motion sequence was repeated to evaluate the left posterior semicircular canal. During the test, the patient's neck and head were supported so that they would not be damaged. For the head roll test, the patient laid supine with his head 30° tilted upwards (the lateral canal was parallel to the ground plane), and the head and trunk were simultaneously rotated to both sides (right and left) to see if nystagmus occurred on the horizontal plane. As a result of Dix-Hallpike test and Head roll test; If findings consistent with peripheral nystagmus were observed, that position is accepted as positive. If no symptoms or findings compatible with peripheral nystagmus were observed, it is accepted as negative.

For the VHIT, an Interacoustics EyeSeeCam vHIT (Denmark) device was used. All participants were seated in a fixed chair 1 meter away from the wall. A circle was drawn on the wall at eye level, large enough for the patients to see, for fixation. The headset of the device was tightly worn by the patients. Thus, possible false results were prevented. Head movements were not made rhythmically. As a result of the arrhythmic and irregular head movements, the patient was prevented from moving his/her head. The recording was made in 3 positions: lateral semicircular canals, LARP (left anterior semicircular canal, right posterior semicircular canal), and RALP (left posterior semicircular canal, right anterior semicircular canal). VOR gain values were recorded for each canal. Normal limits for VOR gain are ≥ 0.8 for the left lateral semicircular canal (Left Lateral, LL) and right lateral semicircular canal (Right Lateral, RL); ≥ 0.7 for the left anterior semicircular canal (Left Anterior, LA), right posterior semicircular canal (Right Posterior RP), left posterior semicircular canal (Left Posterior LP) and right anterior semicircular canal (Right Anterior, RA). The results of the patients were evaluated, it was was compared between groups a decrease in VOR gain and whether there was vestibular involvement with the presence of overt / covert saccades.

DHI was asked to all patients. This questionnaire is a psychometric 25-question self-assessment measure of the dizziness handicap (Jacobson & Newman 1990). The scale consists of 25 statements that the patient responds in the format of: "yes" (4 points), "sometimes" (2 points), and "no" (0 points). Thus, 100 points represent the maximum self-report dizziness handicap, and 0 represents the minimum handicap. The survey was conducted face-to-face by an audiologist for all 62 participants.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences version 20.0 software (IBM Corp., Armonk, NY, USA). According to the normality test, continuous variables age and VHIT and DHI scores were found to be incompatible with normal distribution (Kolmogorov-Smirnov Test; p<0.05). The Mann-Whitney U test was used for the comparison of the control and study groups in VHIT; Kruskal Wallis test was used for comparing the VHIT according to the right and left ear hearing degrees; and Chi-square test was used for comparisons of VNG findings. Spearman Correlation Analysis was used to find the correlation between continuous variables. Descriptive statistical methods were also calculated for data evaluation (mean, standard deviation, minimum, maximum, etc.). The results were evaluated at 95% confidence interval and a significance level at p<0.05.

Results

The average age of our control group was 56.7±6.48 years, and the average age of our study group was 58±5.75 years. In the control group, 13 (41.9%) were men and 18 (58.1%) were women. In the study group, 10 (32.3%) were men and 21 (67.7%) were women. There was no statistically significant difference between the study and control groups in terms of age and gender (p>0.05).

Spontaneous nystagmus was observed in none of the participants included in the study. Table 1 shows the comparison of positional tests between the study and control groups. Peripheral nystagmus was found to be significantly higher in patients with SNHL. The nystagmus observed in the positional tests such as head shake test, right and left dix hallpike test and left head roll tests in the case group was found to be statistically significant compared to the control group (Table 1, p<0.05). In the study, mean DHI scores were found to be 24.26±7.5 in the study group and 4.58±3.4 in the control group. The correlation between DHI scores and positional tests were also assessed. There was a positive correlation between the presence of pathology observed in positional tests and DHI scores in the study group (Table 2, p <0.05).

Mean VOR gain values of the control group Right Lateral 1.05±0.13, Left Lateral 1.08±0.16, Right Anterior 1.20±0.09, vHIT Left Posterior 1.23±0.1, Right Posterior 1 .34±0.07 and vHIT Left Anterior 1.38±0.08. The mean VOR gain values of the case group were Right Lateral 0.99±0.21, Left Lateral 1.01±0.21, Right Anterior 1.18±0.27, Left Posterior 1.11±0.29, Right Posterior 1 .22±0.28 and Left Anterior 1.26±0.29. In Table 3, vHIT VOR gain values were compared between the study and control groups, and no significant difference was observed (p<0.05). In the study group, the correlation between DHI scores and vHIT was also examined, and no statistically significant correlation was found between them (Table 4, p>0.05).

Table 1. Comparison of positional tests between study and control groups

	Study Group			Control Group			
Positional Tests	Negative	Positive	Total	Negative	Positive	Total	p
Head Shake Test	26	5	31	31	0	31	0.02*
Right Dix-Hallpike Test	21	10	31	31	0	31	0.001*
Left Dix-Hallpike Test	22	9	31	31	0	31	0.001*
Left Roll Test	29	2	31	31	0	31	0.151
Right Roll Test	27	4	31	31	0	31	0.039*

*: Chi-square test; p<0.05.

Table 2. Comparison of Dizziness Handicap Inventory and positional tests

	r	p	n
DHI Score * Head Shake Test	0.337	0.007*	62
DHI Score * Right Dix Hallpike Test	0.533	0.001*	62
DHI Score * Left Dix Hallpike Test	0.544	0.001*	62
DHI Score * Left Roll Test	0.307	0.015*	62
DHI Score * Right Roll Test	0.346	0.006*	62

*: Spearman Correlation Analysis; p<0.05, DHI; Dizziness Handicap Inventory.

Table 3. Comparison of VHIT VOR gain values between case and control groups

VHIT	Study Group	Control Group	P
VHIT -Right Lateral	0.99±0.21	1.05±0.13	0.349
VHIT -Left Lateral	1.01±0.21	1.08±0.16	0.207
VHIT-Right Anterior	1.18±0.27	1.20±0.09	0.983
VHIT -Left Posterior	1.11±0.29	1.23±0.1	0.086
VHIT-Right Posterior	1.22±0.28	1.24±0.07	0.485
VHIT-Left Anterior	1.26±0.29	1.28±0.08	0.315

*: Chi-square test; p<0.05, VHIT; Video head impulse test.

Table 4. Comparison between Dizziness Handicap Inventory and VHIT VOR gain values

	r	p	n
DHI Score * VHIT Right Lateral	-0.086	0.504	62
DHI Score * VHIT Left Lateral	-0.133	0.302	62
DHI Score * VHIT Right Anterior	0.028	0.831	62
DHI Score * VHIT Left Posterior	-0.228	0.075	62
DHI Score * VHIT Right Posterior	-0.162	0.208	62
DHI Score * VHIT Left Anterior	-0.186	0.211	62

*: Spearman Correlation Analysis; p<0.05, DHI; Dizziness Handicap Inventory, VHIT; Video head impulse test.

Discussion

In the literature, it has been suggested that hearing loss may accompany vestibular dysfunction due to their anatomical adjacency.[8-10] Therefore, in our study, it was aimed to evaluate the vestibular system of 40- to 65-year-old individuals with and without SNHL with objective and subjective methods. The volunteers with or without SNIK, regardless of their gender, consisting of 31 preson at each group, who are 40-65 year-old are included. First of all, the volunteers are grouped as having normal hearing and sensorineural hearing loss by using audiometric and imitansmetric evaluation. Then, for vestibular evaluation, each participants were subjectively evaluated with the Dizziness Handicap Inventory (DHI), as well as the objective test battery including positional tests with VNG (videonystagmography) and vHIT (video head impulse test) and measurements were compared. Peripheral nystagmus was found significantly higher in patients with SNHL based on the head shake and positional tests. There was a positive correlation between DHI scores and positional test findings of the participants with SNHL. When the vHIT VOR gain values were compared between the groups, there was no significant difference.

Studies in the literature investigating vestibular functions in individuals with hearing loss have been mostly conducted in adults with idiopathic sudden sensorineural hearing loss or specific diseases such as Meniere or benign paroxysmal positional vertigo.[11-14] In addition, we could not find a study comparing the positional test findings in the VNG test battery in adult individuals with SNHL.

There are studies indicating that a generalization cannot be made such as that vestibular dysfunction occurs in every individual with hearing loss.[15-17] Rosenblut et al.[16] (1960) found the relationship between hearing loss and vestibular function to be complex, and the degree of hearing loss is not related to vestibular dysfunction. It was also suggested that there is an etiological parallelism between these two systems and it may be useful to identify hearing loss beforehand.[18] In a study conducted in 124 SNHL individuals, several factors such as hearing loss type, degree of hearing loss, and tinnitus were found compatible with abnormal VNG findings.[9] In our study, similar to this study, the presence of peripheral nystagmus was found to be significantly higher in patients with SNIK after the Head Shake test and in the positional tests. Although the patients who applied to our clinic did not have vestibular complaints, they were compatible with our criteria for peripheral nystagmus. This made us think that the first response that may occur due to the anatomical neighborhood of the cochlea and vestibular system without any complaints may be the presence of nystagmus seen in positional tests.

In a study involving 85 patients, it was found that there was a parallelism between the functional performance of vestibular disorder and DHI.[19] In addition, it is known that patients with posterior and lateral semicircular canal involvement have high DHI scores.[20] Similarly, in our study, a positive correlation was found between the presence of pathology observed in positional tests and DHI scores. Thus, the findings of the participants were evaluated as a result of subjective evaluation as well as objective test methods.

Byun et al.[21] observed that 148 idiopathic sudden SNHL patients had low vHIT VOR gain in the posterior semicircular canals, and suggested that SNHL may be associated with vestibular dysfunction. When 71 patients with dizziness and sudden SNHL were analyzed retrospectively, it was found that VHIT gains in the posterior semicircular canals were abnormal.[13] In our study, when the VHIT VOR gain values were compared between groups, no significant difference was found. This may be due to the differences in the physio-pathology of the diseases, such as presbycusis and idiopathic sudden sensorineural hearing loss.

It has been suggested that there may be a relationship between hearing loss and vestibular dysfunctions due to the anatomical proximity of the cochlea and vestibular organs that share the neural and vascular source.[22] In a NHANES report (the National Health and Nutrition Examination Survey of the USA), a survey research program conducted by the National Center for Health Statistics in the USA, it was stated that the relationship between hearing loss and vestibular dysfunction is high.[23] Hsu et al.[24] also emphasized that pathological changes in SNHL and otolith organ dysfunction should be investigated in a holistic manner in future studies.

Findings of the present study indicated that vestibular involvement is common in 40- to 65-year-old individuals with SNHL. For this reason, it is beneficial to perform vestibular evaluation as well as the evaluation of hearing in 40-year-old or older individuals with SNHL. In addition to objective test methods, subjective evaluations were also conducted in our study. DHI scores were significantly higher in individuals having SNHL than not having SNHL.

First of all, the small number of participants is the most important limitation of this study. Secondly, although patients who applied to our clinic do not have vestibular complaints, the frequency of findings consistent with BPPV clinical features is also high. This may have led to the high number of participants in the study with non-symptomatic BPPV findings in those with sensorineural hearing loss. In this study, the hypothesis that there may be an interaction due to the anatomical proximity of the cochlea and vestibular system was investigated. And finally; It is thought that the first clinical response that may occur as a result of this interaction may be positional vertigo.

Conclusion

In conclusion, vestibular dysfunction may accompany SNHL in subjects over 40 years old. Although the relation is not clear, this association may due to the anatomical proximity of the cochlea and the vestibular system. On the other hand, the timing of symptoms that occur in hearing loss and vestibular system disorders may differ in each one. In other words, it is useful to evaluate patients with hearing loss with the suspicion of having a disorder in their vestibular system because hearing loss can be a sign of vestibular system disorder.

Disclosures

Ethics Committee Approval: This study was approved by Baskent University Institutional Review Board (date: 16.09.2020, project no: KA20/307-20/90).

Peer-review: Externally peer-reviewed.

Conflict of Interest: The authors have no conflict of interest to declare.

Authorship Contributions: Concept – F.U., S.S.E., O.H.C.; Design – F.U., S.S.E., O.H.C.; Supervision – F.U., S.S.E., O.H.C.; Materials – O.H.C., S.S.E.; Data collection &/or processing – F.U.; Analysis and/or interpretation – F.U., O.H.C.; Literature search – F.U.; Writing – F.U., O.H.C.; Critical review - F.U., S.S.E.

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