H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

Original Research

Do Lower Cervical Disc Herniations Cause Vertigo and Tinnitus?

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Submission Date: May 8th, 2024 **Acceptance Date:** August 26th, 2024 **Pub.Date:** April 30th, 2025
Online First Date: March 24th, 2025

Abstract

Objectives: To evaluate the effects of lower cervical disc herniation on the cochleovestibular system.
Materials and Methods: 40 patients with lower cervical disc herniation and 40 healthy individuals were included in the study. A patient demographic data form, Dizziness Handicap Inventory (DHI), Tinnitus Handicap Inventory (THI), Cervical Evoked Myogenic Potentials (c-VEMP) Test, and Pure Tone Audiometry (PTA) Test were applied to all participants. Tinnitus severity and frequency were evaluated in participants with tinnitus.
Results: Of the patients diagnosed with lower cervical disc herniation, 23 (57.5%) had dizziness, and 19 (47.5%) had tinnitus. The tinnitus of the patients was found at a frequency of 6000 Hz and an intensity of 55 dB. A statistically significant difference was found between the groups both in terms of c-VEMP wave presence and in P1 latency and P1-N1 amplitude values ($p<0.05$).
Conclusion: A positive correlation was found between lower cervical disc herniation and audiovestibular findings. The audiological evaluation of these patients, together with neurosurgical examination, is clinically important for the follow-up of the process.

Keywords: *lower cervical disc herniation, vertigo, tinnitus, vestibular evoked myogenic potentials, balance*

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H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
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Introduction

Lower cervical disc herniation is a disc disease causing vascular, anatomical, and biochemical changes in the lower cervical intervertebral disc due to degeneration (Richardson et al., 2007). The prevalence of cervical disc herniation, which increases with aging, is known to be 45%. The most common site is the C6-C7 level, followed by the C5-C6 level, and less frequently the C4-C5 level, with the C7 root being the most affected area (Sharrak & Khalili, 2022; Al Ryalat et al., 2017)

The symptoms of the disease vary according to the place of involvement and duration and severity of the disease. Patients usually apply to the clinic with complaints of sharp pain, such as a knife stabbing sensation and electric shock concentrated in the neck, occipital region, shoulders, and upper extremities. Different problems such as dizziness, headache, imbalance, tinnitus, hearing loss, coordination disorder, diplopia, which increase with neck movements due to the influence of the vertebral arteries and the sympathetic nervous system, can also be seen (Brandt, 2010; Binder, 2007). Dysfunction of mechanoreceptors as a result of degeneration in the cervical region affects the vestibulospinal reflex and disrupts the balance (Hülse &Hölzl, 2000). The human body maintains balance through the integration of proprioceptive, visual, and vestibular inputs (Karnath, 1994). Impairment of proprioceptive information originating from the cervical region causes sensory information not to be transmitted properly enough, and in this case, dizziness or imbalance occurs (Dıraçoğlu et al., 2009). Depending on the level of cervical disc herniation, the possibility of dizziness varies. Hearing loss and tinnitus can also be seen in patients with a pathology affecting the cervical region. It is observed especially as a result of degenerative pathologies occurring in the cervical region pressing on the vertebral artery (Kaech& Kalvach, 1995). Nutrition of the vestibulocochlear structure is carried out by the basilar artery (Fife, 2010). Impairment of the function of the vertebrobasilar artery due to intrinsic and extrinsic factors affects the nutrition of the vestibulocochlear system. As a result of this influence, the patient may experience hearing loss, tinnitus, hyperacusis, vertigo, drop attacks, a sense of imbalance, and ataxia (Koyuncu et al., 1995; Budway & Senter, 1993). This research was carried out to examine the effect of lower cervical disc herniation on the cochleovestibular system.

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

Methods

Research Design

In this study, a descriptive study design was used to gain insight into the effects of lower cervical disc herniation on the auditory and vestibular systems.

Individuals

The study included volunteers who were diagnosed with lower cervical disc herniation through detailed neurological examination and radiological imaging at the neurosurgery outpatient clinic, aged between 18 and 60, with no communication disability, cognitive problems, chronic disease, visual, proprioceptive and vestibular system pathology that could affect balance and hearing loss, a pathology affecting middle ear functions, motor deficit, complaint of drowsiness and have normal carotid vertebral artery doppler. For the control group, healthy volunteers who did not have lower cervical disc herniation in their radiological examinations were included in the study. The study sample was determined by power analysis. According to the calculation made using the G*power 3.1 program, with a 0.80 effect size, 0.05 margin of error, 0.95 confidence level, and 0.95 population representation power, the sample size was calculated as 70 (patient 35, control 35) (Faul et al., 2009). The study was completed with a total of 80 individuals, 40 patients and 40 controls, who accepted to participate in the study and met the inclusion criteria. A simple random sampling method, one of the probability sampling methods, was used to determine the participants.

Data Collection

The research was carried out prospectively in the Audiology Unit of the Ear Nose and Throat Clinic at a university hospital between August 2021 and April 2022. A Patient Demographic Data Form, the Dizziness Handicap Inventory (DHI), the Tinnitus Handicap Inventory (THI), the Cervical Evoked Myogenic Potentials (c-VEMP) Test, and a Pure Tone Audiometry (PTA) Test were applied, and both air and bone conduction hearing thresholds and tinnitus frequency and severity of those with tinnitus were measured.

Data Collection Tools

Dizziness Handicap Inventory (DHI)

The scale consists of 3 subdomains: physical, emotional, and functional. It is used to subjectively measure the level of disability related to balance problems. The DHI was administered to the individuals with dizziness. Physical, emotional, functional, and total scores were obtained according to the yes (4 points), sometimes (2 points), and no (0 points) answers given to the questions (Canbal et al., 2016).

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

Tinnitus Handicap Inventory (THI)

The scale consists of 25 items in total and is used to evaluate the level of tinnitus of the participants. The total score was determined according to the yes (4 points), sometimes (2 points), and no (0 points) answers (Aksoy et al., 2007).

Cervical Evoked Myogenic Potentials (c-VEMP) Test

This is an electrophysiological test that measures the responses of the sternocleidomastoid (SCM) muscle as a result of stimulating the saccule by sending high-intensity sound with a Neurosoft brand Neuro-Audio model device. Superficial electrodes were used to record the responses. The ground electrode was placed in the middle of the forehead, the reference electrode was placed on the upper end of the sternum, and the active electrode was placed on 1/3 of the sternocleidomastoid (SCM) muscle. In order to obtain electromyography (EMG) recordings, individuals were asked to turn their heads to the opposite side of the stimulated side. Measurements were made by sending a 500 Hz tone-burst stimulus at 110 dB nHL volume through ER3A insert earphones. To confirm the reliability of the responses obtained, c-VEMP waves were taken as 2 traces. P1 (P13) waves with positive peaks and N1 (N23) waves with negative peaks were recorded. The absence of P1 and N1 waveforms or observation of abnormal waveforms was defined as “no response”. P1 and N1 absolute latencies, P1-N1 interlatency, and P1-N1 amplitude and the percentage of the asymmetry of the obtained waves were evaluated.

Pure Tone Audiometry Test

To determine the airway and bone conduction hearing thresholds, a Pure Tone Audiometry Test was applied with the Interacoustics-Clinical Audiometer AC40 device. Airway hearing thresholds were evaluated between 250 and 8000 Hz with the TDH-39 earphones, while bone conduction thresholds were evaluated between 500 and 4000 Hz with the B71 bone vibrator. The presence of tinnitus was questioned in the patient whose airway and bone conduction thresholds were determined. Different frequencies were sent to the contralateral ear of individuals with tinnitus, and they were asked to match the frequency of the existing tinnitus. To determine the severity of tinnitus, the frequency of which was determined, different intensities of sound were sent to the contralateral ear, and the patient was asked to match the severity of the existing tinnitus.

Doi: 10.21020/husbfd.1480258

Ethical Principles

Permission was obtained from the University's Health Sciences Institute Non-Interventional Clinical Research Ethics Committee (Decision number: 2021/2208) and from all individuals participating in the study.

Statistical Analysis

The analysis of the data included in the research was carried out using the SPSS (Statistical Program in Social Sciences) 25 program. The Kolmogorov-Smirnov Test was used to check whether the data included in the study matched the normal distribution (Alpar, 2016). The significance level (p) was taken as 0.05 for the comparison tests. Since it did not provide a normal distribution in the variables ($p>0.05$), the analysis was continued with non-parametric test methods. Comparisons in independent pairs were made with the Mann-Whitney U test since the assumption of normality was not provided. In the analysis of the categorical data, Chi-square ($\chi 2$) analysis was performed by creating cross tables. Pearson's correlation analysis was performed to examine the relationship between the measurement values. Pearson's correlation coefficient was used because of the normal distribution.

Results

In the study, the participants were divided into two main groups: the case group (n=40), consisting of individuals with lower cervical disc herniation, and the control group (n=40) consisting of healthy individuals.

The mean age of the case group was 48.5±7.02 years, and that of the control group was 46.7±5.37 years. When evaluated according to the age variable, no significant difference was found between the groups ($p>0.05$). Of the individuals included in the case group, 27 (67.5%) were female, 13 (32.5%) were male, 23 (57.5%) of the individuals included in the control group were female, and 17 (42%, 5) were male. When evaluated according to the gender variable, no significant difference was found between the groups ($p>0.05$, Table 1). The groups showed a homogeneous distribution according to age and gender variables. When the tinnitus severity and frequency of individuals with tinnitus were evaluated, the median value was found at a frequency of 6000 Hz and an intensity of 55 dB (Table 1).

Table 1. Basic descriptive features of the groups

Variables		Case Group	Control Group Rate (%)	Total	Test Value	p Value
Sex	Female	27 (67.5%)	23 (57.5%)	50 (62.5%)	0.855	0.355
	Male	13 (32.5%)	17 (42.5%)	30 (37.5%)		
	Total	40 (100%)	40 (100%)	80 (100%)		
Age		Mean ± SD (Min-Max)			**Test Value**	**p Value**
		48.5±7.02 (31-60)	46.7±5.37 (38-56)		1.306	0.195
		Mean ± SD (Min-Max)			**Median Value**	
Tinnitus Frequency		5473.68 ± 189644 (1000-8000)			6000	
Tinnitus Severity		53.95 ± 9.06 (40-70)			55	

*Test Value[a]: Chi-square Test Value (χ^2), SD: Standard deviation. Test Value[b]: Test of significance of the difference between two means (t-test), p value: Statistical significance, *p<0.05: There is a statistically significant difference between the groups.

In the study, disc herniation locations of the individuals included in the case group were mostly observed at C5-C6 (32.5%) and C4-C5/C5-C6 (32.5%) levels (Figure 1). Of the individuals in the case group, 23 (57.5%) had dizziness, and 19 (47.5%) had tinnitus (Figure 2).

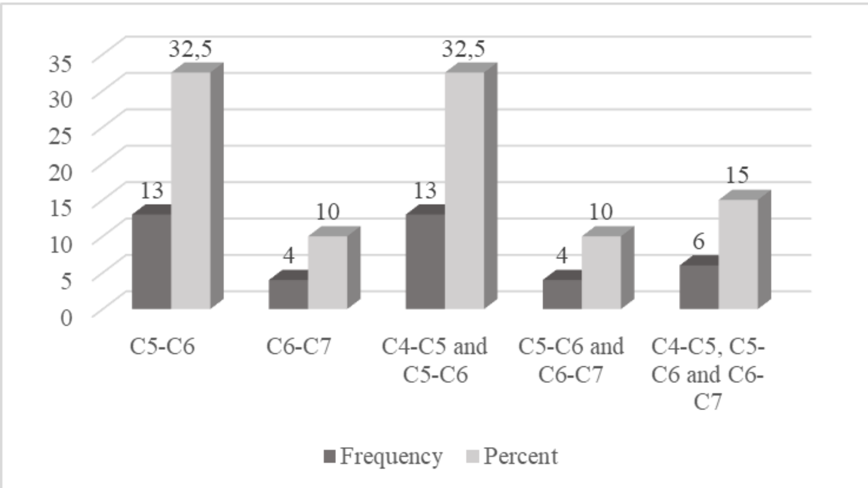

Figure 1. Location of disc herniations in the case group

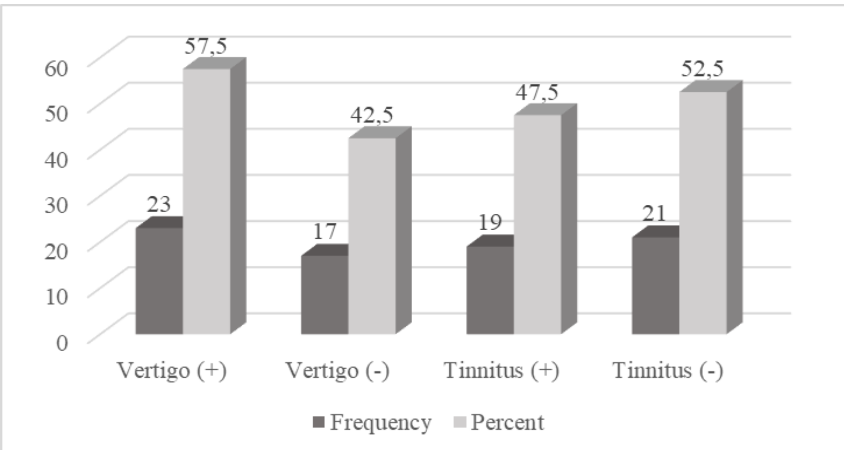

Figure 2. Vertigo and tinnitus incidence rate in the case group

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

No statistically significant difference was found between individuals with and without tinnitus in terms of gender, location of the disc herniation, and age ($p>0.05$, Table 2). A statistically significant difference was found between those with and without tinnitus in terms of the presence of dizziness ($p<0.05$, Table 2).

Table 2. Comparison of individuals with and without tinnitus by variables

Variables		**Tinnitus**		**Total**	**Test Value**	**p Value**
		Yes Number (%)	**No**			
Sex	Female	14(73.7%)	13(61.9%)	27(67.5%)	0.636	0.425
	Male	5 (26.3%)	8 (38.1%)	13(32.5%)		
Location of Disc Hernia	C5-C6	6 (31.6%)	7 (33.3%)	13(32.5%)	0.091	0.764
	C6-C7	2 (0.5%)	2 (9.5%)	4 (10.0%)		
	C4-C5 and C5-C6	7 (36.8%)	6 (28.6%)	13(32.5%)		
	C5-C6 and C6-C7	2 (10.5%)	2 (9.5%)	4 (10.0%)		
	C4-C5, C5-C6, and C6-C7	2 (10.5%)	4 (19.0%)	6 (15.0%)		
Dizziness	Yes	17(89.5%)	6 (28.6%)	23(57.5%)	**16.634**	**0.001***
	No	2 (10.5%)	15(71.4%)	17(42.5%)		
Variable		Mean ± SD (Min-Max)		Median Value		
Age	Tinnitus (+)	47.11±7.35 (31-59)		48.0	155	0.236
	Tinnitus (-)	49.76±6.63 (38-60)		50.0		

*SD: Standard deviation, p value: Statistical significance, *$p<0.05$: There is a statistically significant difference between the groups.

In the participants included in the study, a statistically significant difference was found between the case and control groups according to the physical, emotional, functional, and total scores of the Dizziness Handicap Inventory and the Tinnitus Handicap Inventory total scores ($p<0.05$, Table 3). While there was no statistically significant difference between the participants with and without tinnitus in terms of physical, emotional, and functional disability, which are the sub-dimensions of the Dizziness Handicap Inventory ($p>0.05$, Table 3), a statistically significant difference was found between those with and without tinnitus according to the Dizziness Handicap Inventory total score ($p<0.05$, Table 3).

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

Table 3. Comparison of groups according to scale scores

Scales	Case Group	Control Group	p Value	Tinnitus (+)	Tinnitus (-)	p Value
	Mean ± SD (Min-Max) Median Value					
Physical Disability	15.11 ± 6.33 (2-24) 16	0.35 ± 0.77 (0-2) 0	**0.001***	15,53 ± 6,27 (2-4) 16	8 ± 0 (8-8) 8	**0,444**
Emotional Disability	14 ± 8.77 (0-30) 15	0.3 ± 0.72 (0-2) 0	**0.001***	15,18 ± 9,41 (0-30) 16	10 ± 4,9 (4-16) 8	**0,319**
Functional Disability	21.57 ± 12.56 (0-40) 24	0.2 ± 0.61 (0-2) 0	**0.001***	22,59 ± 12,59 (0-40) 24	18,67 ± 3,19 (4-38) 20	**0,473**
DHI Total	26.9 ± 30.85 (0-90) 11	0.85 ± 1 (0-2) 0	**0.001***	47,68 ± 30,06 (0-90) 60	8,1±16,17 (0-52) 0	**0,001***
THI Total	68.11 ± 25.41 72	0.65 ± 0.95 0	**0.001***	68,11 ± 25,41 (10-98) 72	(-)	

* SD: Standard deviation, Test Value: Mann Whitney U Test, p value: Statistical significance, *p<0.05: There is a statistically significant difference between the groups.

A statistically significant difference was found between the case and control groups according to the presence of c-VEMP waves in the participants included in the study ($p<0.05$, Table 4). While there was no statistically significant difference in the c-VEMP test, N1 latency, and P1-N1 interlatency values ($p>0.05$), a statistically significant difference was found between the case group and the control group in P1 latency and P1-N1 amplitude values ($p<0.05$, Table 4).

Table 4. Comparison of c-VEMP results by groups

Variable		Case Group	Control Group	Test Value	p Value
		Number (%)			
c-VEMP	Wave	64 (80.0%)	78 (97.5%)	**13.788**	**0.001***
	No Wave	16 (20.0%)	2 (2.5%)		
		Mean ± SD (Min-Max) Median Value			
	P1 Latency	13.46 ± 1.19 (10.7-16.7) 13.2	13.09 ± 0.71 (11.5-14.8) 13.1	**1862.500**	**0.013***
	N1 Latency	21.79 ± 2.07 (18.7-25.9) 21.3	21.09 ± 1.84 (18.7-25.9) 20.3	2038.000	0.077
	P1-N1 Interlatency	8.34 ± 1.94 (5.3-13.3) 7.9	8.01 ± 1.72 (5-13.2) 7.6	2236.000	0.345
	P1-N1 Amplitude	63.34 ± 26.78 (15.9-154.1) 56.8	81.82 ± 24.9 (41.5-146) 80.9	**1449.000**	**0.001***

* Test value: Chi-square Test value ($\chi2$), p value: Statistical significance, *p<0.05: There is a statistically significant difference between the groups.

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

In the case group, a moderate statistically significant relationship was found between the DHI total (r=0.630), physical (r=0.440), emotional (r=0.625), and functional (r=0.642) subscale scores and the THI total score of the patients with tinnitus (p<0.05, Table 5, Figure 3).

Table 5. Correlation relationship between scale scores in patients with tinnitus

Dependent Variables	Independent Variables	r Value	p Value
Physical Disability	THI Total	0.440	0.077
Emotional Disability		0.625	**0.007***
Functional Disability		0.642	**0.005***
DHI Total		0.630	**0.004***

* r: Pearson's correlation coefficient, p: Statistical significance, *p<0.05: There is a statistically significant relationship between the scores.

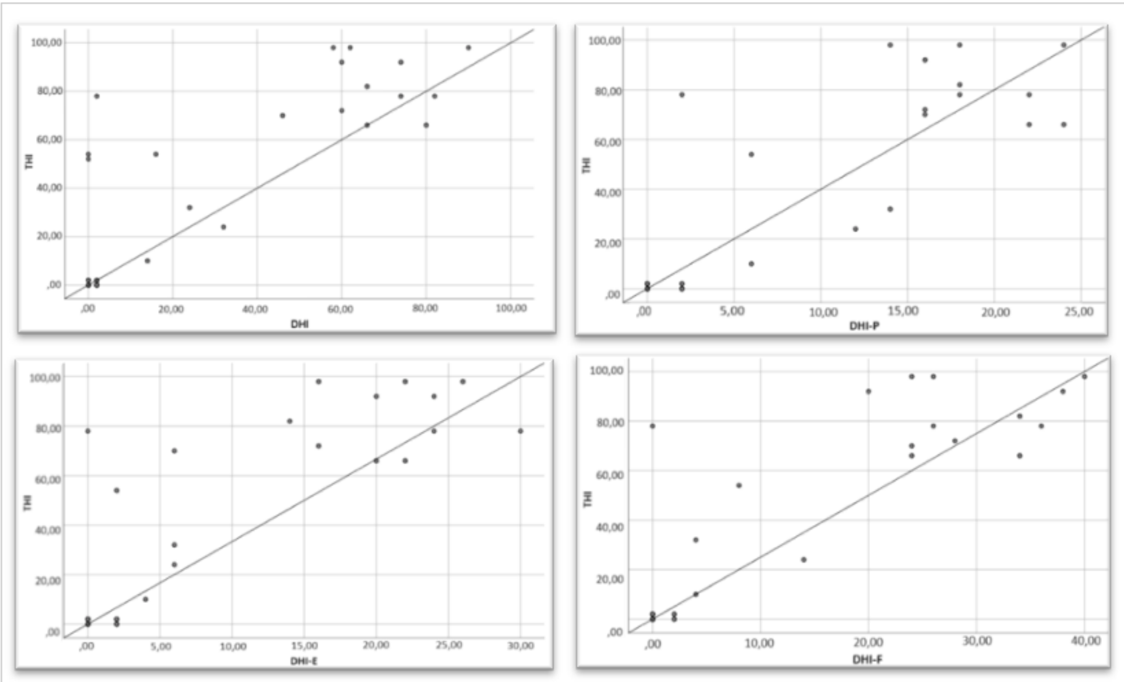

Figure 3. Relationship between THI and DHI total score and subscores (THI: tinnitus handicap inventory, DHI: dizziness handicap inventory, P: physical, E: emotional, f: functional)

Discussion and Conclusion

Since cervical degenerative diseases are the most common group among all neck diseases, cervicogenic vertigo occurs most commonly in this group (Hain, 2015). The deep intervertebral muscles in the cervical spine have an important role in postural control as they have high density muscle spindles (Dıraçoğlu et al., 2009; Wolff, 2013). In addition, cervical

Doi: 10.21020/husbfd.1480258

afferents play a role in the control of balance by working in coordination with the cervico-colic reflex, cervico-ocular reflex, and tonic neck reflex, all of which are associated with the vestibular system (Treleaven, 2008). Considering this information in the literature, the aim of our study was to investigate the effect of lower cervical disc herniation on audiovestibular findings.

Cervical disc herniation increases with age, and it is seen especially around the age of 60 (Al-Ryalat et al., 2017). It has been determined that the age of development of intervertebral disc herniation is approximately between age 45 and 54 years (Ernst et al., 2005). The mean age of the case group in our study was also similar to the literature. The cervical region most affected by cervical disc herniation is the C7 root, with the most common location being the C6-C7 level, followed by the C5-C6 level, and less frequently the C4-C5 level (Al-Ryala et al., 2017; Ernst et al., 2005). In our study, it was seen that cervical disc hernia mostly affected C5-C6 levels, which is compatible with the literature.

One of the most common findings in clinical examinations of cervical disc pathologies is tinnitus (Galm et al., 1998). Cervical musculoskeletal problems are among the somatosensory causes in the etiology of tinnitus (Kemaloğlu et al., 2013). The extension of the cervical spinal nerves towards the auditory system may explain the tinnitus complaint (Koning, 2020a). In a limited number of studies, it has been stated that the most prominent cervical nerves associated with tinnitus pathogenesis are nerves at the C2, C5, and C8 levels (Koning & Ter Meulen, 2019; Koning, 2020b). Koning stated that tinnitus decreased in 18% of individuals as a result of the treatment applied to the afferent cervical nerves at C6 and C7 levels in patients with tinnitus complaints (Koning, 2020b). Although tinnitus is seen in approximately 17% of the population as one of the most common otologic complaints (Jastreboff, 1998), this rate was approximately 47.5% in the case group in our study. The fact that the rate of tinnitus in patients with cervical disc herniation is significantly higher than the rate in the normal population strengthens the relationship between lower cervical problems and tinnitus. In addition, it is noteworthy that the individuals with lower cervical disc herniation in our study had a statistically higher Tinnitus Handicap Inventory score than the control group. In addition, while studies in the literature with individuals with tinnitus indicate that tinnitus severity varies in the range of 33 dB - 47 dB (Kayıkçı, 2000), the present finding of the tinnitus severity of patients with tinnitus complaints as 55 dB on average further strengthened this relationship. In addition, tinnitus frequency mappings of patients with lower cervical disc herniation in our study were obtained at approximately 6000 Hz. Since tinnitus severity and frequency mapping have not been studied

Doi: 10.21020/husbfd.1480258

in the literature in patients with lower cervical disc herniation, it is thought that this information will contribute significantly to the literature.

It is stated that vertigo often occurs in individuals with cervical disc degenerative disease (Galm et al., 1998). The incidence of vertigo complaints in patients with cervical spondylosis is reported to be 50%-65% (Karlberg et al., 1995; Colledge et al., 1996). In addition, it is stated that complaints of dizziness and imbalance in patients with neck herniation are seen in approximately 50% of the patients (Oosterveld et al., 1991; Skovron, 1998). In our study, the complaint of vertigo was seen in 57.5% of patients with lower cervical disc herniation, which is consistent with the literature. At the same time, the fact that the DHI total and sub-dimension scores of the case group were statistically higher than the control group draws attention to the relationship between lower cervical disc hernia and vertigo. Previous studies have demonstrated a strong association between cervical levels and vertigo, demonstrating that vertigo in patients with cervical spondylosis can be successfully managed with anterior cervical discectomy and fusion (Hong & Kawaguchi, 2011; Li et al., 2012). This relationship is explained by the anatomical connections between the cervical spine receptors and the vestibular nuclei (Bankoul et al., 1995; Neuhuber & Zenker, 1989; Neuhuber & Bankoul, 1992; Neuhuber & Bankoul, 1994).

It is stated that degenerative cervical disc pathologies may be associated with vertigo or a sense of imbalance due to strong connections between cervical dorsal roots and vestibular nuclei via neck proprioceptors (Yacovino & Hain, 2013; Brandt and Bronstein, 2001). Shirley et al. reported that there was no statistically significant difference between P1 latency, N1 latency, P1-N1 latencies, and P1-N1 amplitudes in the c-VEMP test results they applied to the case group with spinal cord lesions and the control group consisting of healthy individuals. In addition, they stated that they applied the sound-evoked triceps myogenic potential (SETMP) test to these groups and that there was no or less SETMP response in the group with spinal cord lesions (Shirley et al., 2015). Similarly, Kastanioudakis et al. stated that there was no statistical difference between P1 latency, N1 latency, P1-N1 latencies, and P1-N1 amplitudes in the c-VEMP test results they applied to the groups with cervical myelopathy and cervical spine surgery. In the same study, they also stated that there was no statistically significant difference between P1, N1, P1-N1 latency, and P1-N1 amplitudes in c-VEMP evaluations before surgery and at the 1st and 4th months after surgery in patients who had cervical spine surgery. Comparison of cervical levels of pathologies with c-VEMP results in this study shows the relationship between the locations of pathologies and c-VEMP. However, the absence of a

Doi: 10.21020/husbfd.1480258

control group in this study could not reveal the effect of cervical myelopathy and cervical spine surgery compared to healthy subjects (Kastanioudakis et al., 2017). In our study, contrary to the data in the literature, the effect of lower cervical disc herniation on c-VEMP is seen. It was found that c-VEMP waves were obtained statistically significantly less in the group with lower cervical disc herniation compared to the control group. In addition, while there was no statistically significant difference in N1 latency and P1-N1 interlatency values between the case and control groups in our study, a statistically significant difference was found in P1 latency and P1-N1 amplitude values. These differences in c-VEMP waves in patients diagnosed with lower cervical disc herniation show the effect of lower cervical disc herniation on the vestibulo-colic reflex arc. When the reflex is examined anatomically, it is found that the neural fibers of the medial vestibulospinal tract occur at the motor neurons of the spinal cord at C5 levels and then enter the SCM via the spinal accessory nerve (Colebatch et al., 1994). This arc explains the less acquisition of c-VEMP wave, the delay in P1 latency, and the decrease in P1-N1 amplitude values in patients with lower cervical disc herniation in our study.

Although there are attempts to draw attention to vertigo and tinnitus complaints in cervical disc pathologies in the literature, there are not enough studies. No studies have been found that specifically evaluate these symptoms in the lower cervical region and examine their correlations. In our study, it was shown that vertigo symptoms were statistically higher in individuals with tinnitus. In addition, the DHI total score was statistically higher in individuals with tinnitus. In addition, we examined the correlations between THI total and sub-dimension scores and THI scores in our study. We showed that there was a moderate statistically significant correlation between THI total score, emotional subscale score, functional subscale score, and THI total score. In light of these findings, the relationship of lower cervical afferents involved in balance with cervico-colic reflexes (Kemaloğlu et al., 2013) and the extension of lower cervical spinal nerves to the auditory system (Jastreboff, 1998; Kayıkçı, 2000; Karlberg et al., 1995) draws attention to the fact that vertigo and tinnitus appear together in lower cervical pathologies, as well as they are related.

Our research has shown that cervical disc herniations, whether or not there is cord compression, may cause audiovestibular findings because they affect the muscular system. The study also pointed out that there is a correlation between vertigo and tinnitus symptoms in patients with lower cervical disc herniation. Based in these results, it is recommended that patients diagnosed with lower cervical disc herniation be evaluated audiologically, and a multidisciplinary approach should be adopted. We believe that evaluating the audiological findings of lower cervical disc herniation before and after the treatment will provide information about the effectiveness of the treatment.

In disc herniation, the severity of pressure on the nerve root is also important. A limitation of our study is that audiovestibular findings were not compared according to the pathological classification of cervical disc herniations. Accordingly, in future studies, audiovestibular findings can be compared using the MacNab classification of disc herniation or the classification according to root compression defined by Van Rijn. Additionally, in future studies, pre- and postoperative comparisons can be made, and groups can be evaluated with a larger sample size and additional vestibular test batteries.

Acknowledgment

We would like to thank our patients who participated in our study for their contribution.

Funding

No financial support was received within the scope of the study.

Conflict of interest

There is no conflict of interest between any institution, organization, or researchers within the scope of the study.

H.Ü. Sağlık Bilimleri Fakültesi Dergisi
Cilt:12, Sayı: 1, 2025
Doi: 10.21020/husbfd.1480258

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