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Original Article

Assessment of Vestibular Function in Adults with Prelingual Hearing Loss Using c/oVEMP Tests

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OBJECTIVES: The aim of the present study was to compare the vestibular system integrity of individuals with normal hearing with that of prelingual hearing impaired individuals. It is well known that ocular vestibular evoked myogenic potentials (oVEMPs) reflect utricular function, whereas cervical vestibular evoked myogenic potentials (cVEMPs) reflect saccular function. Therefore, oVEMP and cVEMP tests were applied to evaluate the vestibular system integrity of hearing impaired individuals participating in the research.

MATERIALS and METHODS: The study group consisted of sensorineural prelingual hearing-loss volunteers aged from 18 to 60 years, whereas the control group consisted of age- and gender-matched healthy volunteers. cVEMP and oVEMP tests were performed to evaluate the integrity of the vestibular system, and the results were compared with those of the control group.

RESULTS: The study included 20 (76.9%) women and 6 (23.1%) men in the study group; on the other hand, the control group consisted of 19 (73.1%) women and 7 (26.9%) men. There was a difference between the study group and the control group when oVEMP and cVEMP responses were compared, and the response percentage was higher in the control group. The response rates of oVEMP and cVEMP in patients with prelingual hearing loss were 44.2% and 59.6%, respectively. There was also a statistically significant difference between the groups for oVEMP amplitude and cVEMP P1 latency ($p \leq 0.05$).

CONCLUSION: These findings suggest that prelingual hearing loss is related to both utricular and saccular dysfunctions. However, oVEMPs were more often abnormal in prelingual deaf patients than cVEMPs, suggesting that utricular dysfunction may be more common than saccular dysfunction.

KEYWORDS: Ocular vestibular evoked myogenic potential, cervical vestibular evoked myogenic potential, vestibular function tests, prelingual, sensorineural hearing loss

INTRODUCTION

Prelingual hearing loss is defined as hearing loss occurring prior to the completion of speech and language development. The cochlea and peripheral vestibular organs are in close embryological, physiological, and anatomic relationships, suggesting that in individuals with sensorineural hearing loss, any cochlear disorder may also lead to a number of changes in the peripheral vestibular organs [1].

Although coordination disorders, clumsiness, and balance problems have been frequently reported among individuals with prelingual hearing loss, routine screening and rehabilitation programs do not focus on these complaints, and unless an individual presents with a marked balance problem, it is usually missed [2].

Vestibular evoked myogenic potentials (VEMP) are electrophysiological tests where the reflex arch's integrity is tested by making measurements from muscles after stimulating the peripheral vestibular organs in different ways. VEMP is in fact an electromyographic record. If a reflex arc response is measured from the sternocleidomastoid (SCM) muscle, it is designated as cervical vestibular evoked myogenic potential (cVEMP); on the other hand, if it is measured from the extraocular muscles, it is designated as oc-

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ular vestibular evoked myogenic potential (oVEMP). In VEMP test, air conduction sound, bone conduction sound, vibration, and galvanic (electrical) current can be used for stimulation. It has been reported that the saccule and inferior vestibular nerves play important roles for cVEMP formation, and the utricle and superior vestibular nerves play important roles for oVEMP formation. Therefore, using both tests together plays a complementary role for the evaluation of the peripheral vestibular system integrity and functions.

Vestibular evoked myogenic potentials test can be used in daily practice to diagnose and follow-up many vestibular disorders, such as Meniere disease, vestibular neuritis, vestibular schwannoma, and superior semicircular canal dehiscence syndrome [3-5].

The aim of the present study was to compare the vestibular system's integrity between individuals with prelingual hearing impairment and individuals with normal hearing. In line with this objective, oVEMP and cVEMP tests were applied to test the vestibular system integrity among individuals with hearing disability enrolled in the study.

MATERIALS AND METHODS

This prospective controlled clinical study was conducted at the ORL Department Audiology, Speech, and Voice Disorders Unit. The study was approved by Baskent University Medical and Health Sciences Research Committee (project no.: KA 17/70) and was supported by the University Research Fund. All participants signed a volunteer subject informed consent form. Informed consent was obtained from all the participants.

The study group consisted of individuals with prelingual hearing loss. All individuals underwent cVEMP and oVEMP tests to record latency and amplitude values. The results were compared with those obtained from the same number of age- and sex-matched healthy controls. Individuals with any neuro-otologic complaint, history of operation, head trauma, or any disorder limiting movements of the cervical region were excluded from the study.

The tests were performed using a Grason-Stadler (GSI) Audera device (Grason-Stadler Inc., MN, USA). All study participants first underwent skin cleansing using alcohol and a peeling gel. Single-use Ag/AgCI (Ambu Blue Sensor N Ref No N-00-S/25) superficial electrodes were used for each test.

Table 1. Gender distribution of the study participants

	Study group	Control group	Total
Female	20 (76.9%)	19 (73.1%)	39 (75%)
Male	6 (23.1%)	7 (26.9%)	13 (25%)
Total	26 (100%)	26 (100%)	52 (100%)

Table 2. oVEMP and cVEMP response rates of the study participants

		Study group	Control group
oVEMP	Responsive	23 (44.2%)	47 (90.4%)
	Unresponsive	29 (55.8%)	5 (9.6%)
cVEMP	Responsive	31 (59.6%)	52 (10.0%)
	Unresponsive	21 (40.4%)	0 (0%)

oVEMP: ocular vestibular evoked myogenic potentials; cVEMP: cervical vestibular evoked myogenic potential

oVEMP Test Technique

Reference electrodes were placed 5 mm below the eye sockets on the inferior oblique muscle. Active electrodes were placed 1–2 cm below the reference electrodes, and the ground electrode was placed on the forehead. Electrode resistances were kept <5 µΩ. During the recording, volunteers in the sitting position were asked to look at objects previously placed 1 m away at 30°–40° angles on a horizontal plane with neutral gaze line for the duration of sound. While giving stimuli via an insert earphone, recording was made from the contralateral eye. During ear changeover, the individuals were asked to rest with their eyes shut. The apices of the first waveform that was formed after the introduction of the stimulus were designated as N1 and P1. The latency and amplitude values of the waves were then measured.

cVEMP Test Technique

Active (recording) electrode was placed on the middle 1/3 of the SCM muscle, the inactive electrode to the origin of the muscle in the neck region slightly below the first one, and the ground electrode below it. The patients were asked to contract the SCM muscle to record cVEMP values. This was achieved by a sitting patient slightly lifting his/her head or turning it opposite to the stimulated side. The apices of the first waveform that was formed after the introduction of the stimulus were designated as P1 and N1. The patients were allowed to rest when they were fatigued. The tests were described to the participants with prelingual hearing loss using a sign language.

All participants were administered the Turkish version of the Dizziness Handicap Inventory (DHI) to assess possible vertigo with the scores of the DHI being compared between the groups.

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 24.0 software package (IBM Corp., Armonk, NY, USA). Wilcoxon signed-rank test was used to compare right-sided and left-sided oVEMP and cVEMP values. Mann–Whitney U test was used to test intergroup differences. A $p<0.05$ was considered statistically significant for all comparisons.

RESULTS

A total of 52 subjects were included in the study. All subjects were aged 18–60 years. The gender distribution of the groups is shown in Table 1.

The mean ages were 43.35±9.4 (19–51) years for the study group and 29.96±6.12 (20–45) years for the control group.

Higher response rates were obtained for both oVEMP and cVEMP in the control group. There was a statistically significant difference between the study and control groups with respect to the response rates ($p<0.01$, Pearson chi-square test) (Table 2).

Both groups were compared with regard to oVEMP and cVEMP P1 latency, N1 latency, and amplitude levels. There were significant differences between oVEMP amplitudes and cVEMP P1 latencies ($p<0.05$) (Table 3).

A comparison of both groups' DHI scores revealed statistically significant differences with respect to neither total score nor subgroup scores (Table 4).

Table 3. Comparison of the study and control groups with respect to P1 latency, N1 latency, and amplitude levels for oVEMP and cVEMP3

	oVEMP			cVEMP		
	Study group	Control group	p*	Study group	Control group	p*
P1 (ms)	11.49±2.75	11.53±1.94	0.433	17.15±1.76	16.6±2.45	0.034
N1 (ms)	8.9±2.18	9.36±1.96	0.460	26.21±12.15	24.5±2.44	0.970
Amplitude (µV)	5.32±3.73	2.66±1.68	0.003	86.62±9.91	99.82±9.14	0.175

*Mann–Whitney U test
oVEMP: ocular vestibular evoked myogenic potentials; cVEMP: cervical vestibular evoked myogenic potential

Table 4. Dizziness Handicap Inventory scores

	Dizziness Handicap Inventory score			
	Physical	Functional	Emotional	Total
Study group	6.6±6.26	6.2±7.16	6.2±6.09	15±17.7
Control group	5.4±6.4	6.38±9.4	3.6±6.27	15.3±20.8
p*	0.314	0.547	0.638	0.668

*Mann–Whitney U test

DISCUSSION

Our study compared the vestibular system integrity of adult patients with prelingual hearing loss with that of healthy individuals with normal hearing. This comparison was performed using cVEMP and oVEMP tests. cVEMP is used to measure the inhibitory response of the ipsilateral SCM muscle, whereas oVEMP is used to measure the excitatory response of the contralateral extraocular muscles. cVEMP is brought about by the vestibulocolic reflex, and oVEMP is brought about by the vestibuloocular reflex. Therefore, obtaining an abnormal or absent response from these tests suggests an abnormality at some level in these reflex arcs [6].

Whereas a response in cVEMP is elicited by airway click stimulation in 80% of normal individuals, this rate is reduced to approximately 50% with oVEMP. However, it increases to 90% with short tone burst stimulation for both tests. However, click stimulation is regarded as the optimal stimulation technique by virtue of the reproducibility of its results obtained with the first stimulation and its ability to elicit symmetrical results [7]. Different unresponsiveness rates reported in the literature may have been related to both differences in patient populations and methods used for that test [5, 8, 9]. However, studies have shown that both oVEMP and cVEMP yielded results independent of hearing loss [4, 10].

Previous studies of vestibular function in individuals with hearing loss were predominantly conducted among the pediatric age groups. Recently, many studies have shown vestibular dysfunction of varying severity among children with hearing loss. It is believed to occur as a consequence of a close anatomic relationship between the vestibule and cochlea. A review of studies on vestibular functions among children with hearing loss conducted in 2016 has shown that vestibular functions have been assessed using cVEMP in a total of 1358 children with hearing loss in 21 studies and oVEMP in a total of 137 children in 4 studies. When the caloric test was taken as the reference standard, cVEMP had a sensitivity of 71%–100% and a specificity of 30%–100%; when the rotation chair was taken as the reference standard, it showed a sensitivity of 48%–100% and a specificity of 78%–100%. oVEMP had a sensitivity of 83%–93% and a specificity of 86%–95% relative to the caloric test, whereas a sensitivity of 83% and a specificity of 86% relative to the rotation chair [11]. Inoue et al. [1] assessed vestibular functions using caloric test, cVEMP, and rotation chair among children with hearing loss; they reported that those children have a tendency for having vestibular system dysfunction, and that the development of gross motor function is also affected.

It has been reported that vestibular dysfunction occurs at a rate of approximately 70% among children with severe hearing loss [12]. Nevertheless, it is not exactly known how this condition evolves as individuals grow. Among adults with longstanding hearing loss, vestibular dysfunction may be compensated for by central compensation mechanisms as one ages. However, our study results may indicate signs of vestibular system atrophy. The absence of any vestibular symptom or any significant difference between the DHI assessments of the control and study groups may also be explained by the plasticity of sensorimotor input–output mechanisms that emerge early in life [13].

Previous studies have reported varying response rates for both cVEMP and oVEMP. Xu et al. [14] reported unresponsiveness rates of 38.9% for oVEMP and 44.4% for cVEMP among adults with severe prelingual hearing loss with a mean age of 36.6±16.2 years.

On the other hand, Lin et al. [15] reported an unresponsiveness rate of 70% among adults with congenital severe hearing loss (pure tone average (PTA) >90 dB) for oVEMP and added that such a rate is reduced to 20% for adults with moderate-to-severe congenital hearing loss with a PTA better than 90 dB. However, they demonstrated that individuals with severe hearing loss and those with moderate-to-severe hearing loss showed similar unresponsiveness rates for cVEMP (80% vs. 68%). Their study reported results that show some disparities with regard to the unresponsiveness rates obtained by both our study and various other studies in the literature. This may be linked to some methodological factors, such as using bone vibration for oVEMP and sound stimulation for cVEMP [15].

Bansal et al. [5] compared individuals aged 15–30 years with advanced sensorineural hearing loss and the same number of healthy individuals for oVEMP and cVEMP values. cVEMP response could be obtained in all participants of both groups, whereas oVEMP responses could be obtained in 66% of the hearing loss group but 100% of the heathy group. While there was no significant difference between the groups with respect to wave latency, amplitudes were significantly lower in the hearing loss group. In this study, low response rates obtained for oVEMP suggested a greater involvement of utricular functions among individuals with advanced hearing loss. However, in our study, the unresponsiveness rates were 55.8% for oVEMP and 40.4% for cVEMP. This suggests that although utricular functions were affected to a greater degree among our study participants, saccular functions were also affected.

In the present study, a low responsiveness level, together with P1 latency prolongation in cVEMP and amplitude difference in oVEMP, suggests that atrophy in the auditory pathway may also extend to the vestibular system.

CONCLUSION

In the present study, we compared oVEMP and cVEMP tests between adults with prelingual hearing impairment and adults with normal hearing. Our findings suggest prelingual hearing loss related to both utricular and saccular dysfunctions. However, oVEMPs were more often abnormal in prelingual deaf patients than cVEMPs, suggesting that utricular dysfunction may be more common than saccular dysfunction.

Considering that no study with a design similar to that of the present study has been conducted among individuals aged 18–60 years with prelingual hearing loss before, we believe that our study would be influential for the existing literature.

Ethics Committee Approval: Ethics committee approval was received for this study from the Baskent University Institutional Review Board (Project no: KA 17/70).

Informed Consent: Informed consent was obtained from individuals included in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - O.T., A.F.B.; Design - M.V.A., A.F.B., O.T., E.H.; Supervision - A.F.B., E.H.; Resource - O.T., M.V.A.; Materials - O.T., M.V.A.; Data Collection and/or Processing - O.T., M.V.A.; Analysis and/or Interpretation - O.T., M.V.A., E.H.; Literature Search - O.T., M.V.A.; Writing - M.V.A., O.T.; Critical Reviews - M.V.A., E.H.

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

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