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Original Article

Evaluation of the Peripheral Vestibular System in Individuals with Vision Loss

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BACKGROUND: The aim of this study was to determine whether there are differences in the balance system between individuals with vision loss and a healthy control group using the video head impulse test (vHIT), cervical vestibular evoked myogenic potentials (cVEMP) and ocular vestibular evoked myogenic potentials (oVEMP) tests.

METHODS: The study included 23 individuals diagnosed with bilateral low vision, 20 individuals diagnosed with bilateral blindness, and 50 healthy control subjects. vHIT, cVEMP, and oVEMP tests were applied to all participants to evaluate the vestibular system. In addition to the standard vHIT, 2-condition vHIT (in the dark and in daylight without a target) was performed on the control group to evaluate the effect of visual input.

RESULTS: In vHIT responses, a significant difference in vestibulo-ocular reflex (VOR) gains was detected in the comparison between the bilateral low vision, bilateral blind, and control groups in all semicircular canals (SSC) ($P < .001$). When the vHIT responses in the 3 conditional groups of the control group (untargeted daylight, darkness, and standard) were examined, a significant difference in VOR gains was detected in the comparison of all 3 groups in the entire SSC ($P < .001$).

CONCLUSION: The findings of statistically significantly low VOR gains obtained in individuals with low vision and the blind group showed the great effect of visual input on the vestibular system. This hypothesis was also supported by the results of vHIT, which was applied in 3 stages (dark, untargeted daylight, and standard) in healthy individuals.

KEYWORDS: Blindness, vemp, vestibulo-ocular reflex, video head impulse test

INTRODUCTION

Balance is the ability to maintain the body's position in a fixed and certain orientation in an environment with gravity. The visual, somatosensory, and vestibular systems, which are part of the sensory afferent system, work together in coordination to maintain balance.[1] Balance is provided by the information carried by these 3 systems and the regulatory motor reflexes. Blindness is defined as visual perception of less than 3/60 in the better eye or the associated loss of less than 10° of the field of vision.[2] In the absence of visual input, the general balance function is affected, and the individual has a greater need for the proprioceptive and vestibular systems to maintain balance.[3,4] Therefore, a vestibular abnormality in individuals with vision loss increases their vulnerability to falls, and this has a serious effect on the quality of life.[3,4] In conditions such as Usher syndrome and vertebrobasilar insufficiency, vestibular system pathologies have been reported together with vision loss.[5,6] Compared to individuals with normal vision, those with vision loss not only have lower performance in balance control but are also more vulnerable to vestibular disorders such as vestibular neuritis and Ménière's disease.[7] Therefore, the evaluation of vestibular system functions is required when there are potential balance complaints in these individuals.[7] Evaluation of the vestibulo-ocular reflex (VOR) may be difficult in these individuals because of the chronic absence of visual feedback, which can change the neural pathway of oculomotor

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movements, and there is the likelihood of the chronic absence of visual senses changing VOR.[8] The sacculo-collic and utriculo-ocular pathways can be evaluated using cervical vestibular evoked myogenic potentials (cVEMP) and ocular vestibular evoked myogenic potentials (oVEMP) tests in these individuals in the same way as for those with normal vision.[8,9]

The aim of this study was to evaluate the peripheral vestibular system in individuals with vision loss by taking measurements with the video head impulse test (vHIT) and VEMP tests.

METHODS

Participants

The study included patients who underwent an ophthalmic examination in the Ophthalmology Department and were evaluated as having bilateral low vision or acquired bilateral blindness. Diagnoses of low vision and blindness were made according to the definitions in the "World report on vision" published in October 2019 by the World Health Organization.[10] The World Health Organization defines "low vision" as visual acuity between 20/70 and 20/400, with the best possible correction, or a visual field of 20° or less. "Blindness" is defined as a visual acuity worse than 20/400, with the best possible correction, or a visual field of 10° or less.[10] The study sample comprised 23 patients diagnosed with bilateral low vision, 20 patients diagnosed with acquired bilateral blindness, and 50 healthy control subjects. All the study participants underwent the vHIT, cVEMP, and oVEMP tests to evaluate the vestibular system. In addition to the standard vHIT, 2-condition vHIT (in darkness and in daylight without a target) was applied to the control group to evaluate the effect of visual input. All the study participants underwent an ear, nose, and throat examination. The inclusion criteria for each group were defined as age in the range of 18-55 years, no conductive-type hearing loss, no previous or active vestibular disorder, and no diagnosed systemic disease. Participants with congenital blindness or who had a neurological comorbidity were excluded from the study.

Research Procedures

This study was approved by the Institutional Review Board of Başkent University (December 28, 2022, Project no: KA22/499). All procedures were performed in compliance with the ethical standards of the Institutional Review Board and the Helsinki Declaration. Written and verbal informed consent was obtained from all the participants. The study was conducted in the Audiology Unit of the Department of Otorhinolaryngology in Başkent University between January 2023 and March 2024.

MAIN POINTS

- The absence of visual input can affect the vestibular system and restrict vestibulo-ocular reflex (VOR) function.
- Through compensation mechanisms for the lack of visual input, the vestibular and somatosensory systems come into more active use. Thus, the VOR mechanism can be more developed in blind individuals.

The personal and clinical characteristics of all the study participants were questioned, and then the vHIT, cVEMP, and oVEMP tests were applied. The oVEMP test measurements were not taken from the bilateral blind group.

Video Head Impulse Test

The OTO suite Vestibular (Software Version: 3.00 Build 1007, Otometrics) computer program and goggles with an integrated video camera (Type-1085 ICS impulse) were used in the video head impulse test (vHIT) performed to evaluate the vestibular system. The subject was seated upright on a chair at a distance of 1.5 m from the target specified at head height. Before wearing the goggles with the video camera, the cleanliness of the goggle lenses was checked. To ensure that the goggles would not move and slip during the test, care was taken to ensure a tight fit of the goggle band. For the bilateral low vision group and the bilateral blind group, the head of the subject was bent forward at 20° for the lateral canal plane to be parallel to the floor in the vHIT test. As the subjects could not see the target point, they were instructed to just look straight ahead. At this point, the region of interest (ROI) for pupil adjustments was determined and positioned at the center of the video camera. To be able to select the pupil more clearly in some of the subjects with acquired blindness in both eyes, a band was applied to the eyelid and as the ability to see was lost, commands were given verbally and by touching the right or left regions of the goggles. During calibration, the subject was instructed to look straight ahead, and the laser light was then turned on. At this point, the head position was adjusted for the fixation point to be in the center of the laser beams. After completion of the calibration, first the lateral test was started for the evaluation of the lateral semi-circular canal (LSC). The practitioner moved behind the subject and held the head of the subject with both hands without any contact with the goggles or the goggle band. The head was suddenly pushed to the right or left at a small amplitude and high velocity (the rate of head impulse/thrust was approximately 100°-250°/sec for the LSC test). When pushing the head, care was taken not to exceed 15°-20° and not to go beyond the ROI area. Tests were then performed for the evaluation of the left anterior right posterior (LARP) semi-circular canal and the right anterior left posterior (RALP) semi-circular canal, respectively. For these tests, the subject was instructed to look straight ahead and the head position was centered using the device program. The ROIs were then adjusted by turning the head 35°-45° to the right for the LARP test and to the left for the RALP test. As the subject could not see the target when adjusting the ROI, the area to be examined was set by touching the goggles in addition to giving verbal commands. Vertical stimuli were applied in the sagittal plane for the LARP and RALP tests (the rate of head impulse/thrust was approximately 50°-250°/sec for the LARP and RALP semi-circular canal tests). The vHIT was performed in 3 stages for the healthy control group. These 3 stages were as follows: Condition 1: in complete darkness with no target, Condition 2: in a light environment with no target, Condition 3: in a light environment with a fixed target.

The control group participants were informed in detail about the first stage, during which the test would be performed in complete darkness. Each subject was then seated on a chair at a distance of 1 metre from the wall and the goggles with the video camera were worn. The subject was instructed to sit up straight during the test. As there was no target and the test was conducted in complete darkness, the

subject was instructed to open their eyes as wide as possible and to say when they realized that they could see the environment. When the subject became accustomed to the darkness and started to see the environment, the light was turned on and then off again, and the test was continued. Following the same order as for the previous test, the lateral canal, LARP and RALP canals were tested. Then the control group participants were informed in detail about the second stage, during which the test would be performed in a light environment with no target. Each subject was seated on a chair at a distance of 1 metre from the wall and the goggles with the video camera were worn. The subject was instructed to sit up straight during the test and to look straight ahead, as there was no target. In the same way and in the same order as for the previous test, the lateral canal, LARP and RALP canals were tested.

In the third stage, the classic method was applied using a fixed target in a light environment to test the lateral canal and the LARP and RALP canals. When testing the lateral canal, measurements were taken by applying small amplitude high-velocity impulses to the right or left side of the head while the subject was looking at a black target dot straight ahead. The head was turned approximately 35°-45° to the right for the LARP canal test and to the left for the RALP test, and measurements were taken by applying small impulses to the anterior and posterior of the head in the sagittal plane.

Vestibular Evoked Myogenic Potentials Test

The ocular VEMP test was not applied to the bilateral blind group, but the cervical and ocular VEMP tests (cVEMP, oVEMP) were performed on all the other study participants. The Interacoustics Eclipse VEMP (Smart EP 25) device with ER3A (Etymotic Research Inc., Illinois, USA) insert earphones was used for the measurements of the VEMP tests. For both tests, the subject was seated on a chair and, first, the skin was cleaned by wiping with a peeling gel. Four single-use, self-adhesive Ag/AgCl surface electrodes (Ambu Blue Sensor N ref No N-00-S/25) were used for each test. When performing the test measurements, it was checked that the electrode impedance was <5 kohm.

The placement of the electrodes for the cVEMP test was as follows: the reference electrode was placed on the mid-third of the sternocleidomastoid muscle (SCM), the active electrode over the sternoclavicular joint where the SCM muscle is attached to the sternum, and the earth electrode on the mid-section of the forehead. The subject was instructed to bring their head into a flexion position and then rotate it in a contralateral direction to the tested ear. During the test, stimuli were applied to the ear through insert earphones, and measurements were taken of the inhibitory myogenic activity that occurred in the ipsilateral SCM muscle.

The placement of the electrodes for the oVEMP test was as follows: the *reference electrode* on the infraorbital rim region, the *active electrode* on the chin region, and the *earth electrode* on the mid-section of the forehead. The subject was instructed to position their eyes at an angle of 30°-40° between the neutral gaze line and the horizontal axis, and to look at an object at a 1-meter distance continuously for as long as the sound was heard.

The stimuli given during the test were as follows: tone burst stimulus at 500 Hz frequency, 110 dB nHL severity, and 5.1/s velocity. The electromyography signals were amplified and filtered in the range of 10 Hz-750 Hz for cVEMP and in the range of 10 Hz-1000 Hz for oVEMP. During each measurement, 200 stimuli were used. The analysis duration was set as 50 milliseconds (ms). To evaluate the accuracy of the results, at least 2 waveforms were recorded. The waves were marked as the first positive wave (P13) and the subsequent negative wave (N23) formed after the stimulus was applied in the evaluation of the cVEMP test, and the first negative wave (N10) and the subsequent positive wave (P16) formed after the stimulus was applied in the evaluation of the oVEMP test.

Statistical Analysis

Data obtained in the study were analyzed statistically using IBM SPSS v. 25.0 software (IBM SPSS Corp.; Armonk, NY, USA). Conformity of the data to normal distribution was assessed with the Shapiro–Wilk test, and variance homogeneity with the Levene test and Welch test. Quantitative data were stated as mean ± SD or median and interquartile range (IQR) values, and categorical data as number (n) and percentage (%). In the analysis of 3 independent groups of quantitative data, One-Way ANOVA and the Kruskal–Wallis test were used according to the parametric assumptions. When examining differences between the groups, the Dunnett T3 test and the Mann–Whitney *U*-test with Bonferroni correction were used ($P < .017$ taken as the level of significance). In the comparisons of 2 independent groups of quantitative data, the Independent Samples *t*-test and the Mann–Whitney *U*-test were used according to the parametric assumptions. The level of statistical significance in all the tests was set as $P < .05$.

RESULTS

The mean age was 44.5 ± 9.55 years (range, 26-54 years) for the 20 patients diagnosed with acquired bilateral blindness, 40.83 ± 10.56 years (range, 20-54 years) for the 23 patients diagnosed with bilateral low vision, and 29.22 ± 5.56 years (range, 18-43 years) for the 50 healthy control subjects.

Video Head Impulse Test Findings

The descriptive statistics of the vHIT results for the bilateral blind, bilateral low vision, and healthy control groups are shown in Table 1. The VOR gains, especially for the anterior and posterior canals, were found to be extremely low in the acquired bilateral blind group. Lower VOR gains were obtained in the control group in the first condition (simulated blindness) than in the second condition (simulated low vision) and in the third condition (classic method) in all canals.

A statistically significant difference was determined between the groups with respect of VOR gains ($P <.001$) (Table 2). All the SSC VOR gains of the bilateral blind group were determined to be statistically significantly lower than those of the bilateral low vision group ($P < .05$). The left anterior SSC, right anterior SSC, left posterior SSC, and right posterior SSC VOR gains of the bilateral low vision group were found to be statistically significantly lower than those of the control group ($P < .05$). No statistically significant difference was determined between the bilateral low vision group and the control group with respect to the left lateral SSC and right lateral SSC VOR gains ($P > .05$). All the SSC VOR gains of the bilateral blind group were determined to be statistically significantly lower than those of the control group ($P < .05$). In the comparisons of the vHIT responses of the control group, which were designed to be staged with the study group, all the SSC VOR gains of the acquired bilateral

Table 1. The Mean, SD, and Median Values of the Vestibular Ocular Reflex Gain in the Staged Conditions of the Bilateral Blind, Low Vision, and Control Groups

VOR Gain	Persons with Blindness (PWB)			Persons with Low Vision (PWLV)			Control Group								
							Condition 1			Condition 2			Condition 3		
	X	M	SD	X	M	SD	X	M	SD	X	M	SD	X	M	SD
RL	0.82	0.82	0.16	0.96	1.00	0.09	0.91	0.93	0.06	0.97	0.98	0.02	1.00	1.01	0.03
LL	0.74	0.78	0.22	0.92	0.92	0.06	0.87	0.89	0.08	0.91	0.93	0.09	0.96	0.98	0.04
RA	0.61	0.62	0.19	0.83	0.91	0.18	0.78	0.8	0.12	0.86	0.9	0.12	0.94	0.95	0.05
LP	0.57	0.53	0.2	0.8	0.8	0.13	0.75	0.76	0.11	0.83	0.84	0.07	0.91	0.9	0.05
LA	0.5	0.52	0.16	0.62	0.64	0.15	0.68	0.68	0.1	0.8	0.79	0.09	0.88	0.87	0.05
RP	0.54	0.52	0.18	0.69	0.74	0.14	0.71	0.73	0.12	0.81	0.81	0.07	0.91	0.91	0.09

Condition 1: simulated blindness; Condition 2: video head impulse test (vHIT) in daylight without target and without instructions; and Condition 3: vHIT in daylight with standard instructions and target

LA, left anterior semicircular canal; LL, left lateral semicircular canal; LP, left posterior semicircular canal; M, median; RA, right anterior semicircular canal; RL, right lateral semicircular canal; RP, right posterior semicircular canal; VOR, vestibular ocular reflex; X, mean.

blind group were found to be statistically significantly lower than those of the control group in condition 1 (simulated blindness) ($P < .05$). The left anterior SSC and right posterior SSC VOR gains of the bilateral low vision group were found to be statistically significantly lower than those of the control group in condition 2 (simulated low vision) ($P < .001$). No statistically significant difference was determined between the bilateral low vision group and the simulated low vision group (control group in condition 2) with respect to the left lateral SSC, right lateral SSC, right anterior SSC, and left posterior SSC VOR gains ($P > .05$).

Vestibular Evoked Myogenic Potential Findings

In the comparisons of the oVEMP responses of the groups, no statistically significant difference was determined between the bilateral low vision group and the control group ($P > .05$) (Table 3). No oVEMP responses were obtained from the bilateral blind group. When the cVEMP responses of the three groups were compared, no statistically significant difference was determined in respect to the right ear P13 latency value ($P = .138$), left ear P13 latency value ($P = .532$), left ear N23 latency value ($P = .846$), left ear N1P1 latency value ($P = .469$), and the asymmetry ratio between the ears ($P = .298$) ($P > .05$ for all) (Table 4).

DISCUSSION

The aim of this study was to determine whether there are differences in the balance system between individuals with vision loss and healthy control subjects using the video head impulse test (vHIT), cervical vestibular evoked myogenic potentials (cVEMP), and ocular vestibular evoked myogenic potentials (oVEMP) tests.

People perceive their environment through their senses. A deficiency in any one of the senses affects mood, mental health, and social and emotional life due to impaired perception.[11] Balance is closely related to daily living activities, as it is formed with the integrated working of inputs coming from the visual, somatosensory, and vestibular systems. Damage or a deficiency in any one of these systems lays the ground for balance problems.[12] The visual system, which collects 80% of the sensory input, also has significant effects on postural stability. Movement control is coordinated through the eyes. The visual system is beneficial both in the perception of objects and in the process of providing information to the brain about the status of the body.[4]

Blind individuals can achieve balance using vestibular and somatosensory information, which are other forms of sensory information, and VOR can be corrected based on helpful information. To

Table 2. Comparisons of the Vestibular Ocular Reflex Gains Between the Groups

	PWB vs PWLV	PWB vs C3	PWLV vs C3	PWB-PWLV-C3	C1 vs. C2	C1 vs. C3	C2 vs. C3	C1-C2-C3	PWB vs C1	PWLV vs C2
	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value
RL	**.012*[a]**	**<.001*[a]**	**.04*[a]**	**<.001***	**<.001*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**.052*[a]**	.16[a]
LL	**.006*[a]**	**<.001*[a]**	**.02*[a]**	**<.001***	**<.003*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**.045*[a]**	.62[a]
RA	**<.001*[a]**	**<.001*[a]**	**.01*[a]**	**<.001***	**<.001*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**<.001*[a]**	.91[a]
LP	**<.001*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**<.001*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**<.001*[a]**	.1[a]
LA	**<.001*[a]**	**<.001*[b]**	**.01*[a]**	**<.001***	**<.001*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**<.001*[a]**	**<.001*[a]**
RP	**.012*[b]**	**<.001*[b]**	**<.001*[b]**	**<.001***	**<.001*[a]**	**<.001*[a]**	**<.001*[a]**	**<.001***	**<.001*[a]**	**<.001*[a]**

C1, Condition 1: simulated blindness; C2, Condition 2: video head impulse test (vHIT) in daylight without target and without instructions; and C3, Condition 3: vHIT in daylight with standard instructions and target.

LA, left anterior semicircular canal; LL, left lateral semicircular canal; LP, left posterior semicircular canal; PWB, persons with blindness; PWLV, persons with low vision; RA, right anterior semicircular canal; RP, right posterior semicircular canal.

[a]Mann–Whıtney *U*-test with Bonferronı correction-corrected level of significance at $P < .017$.

[b]Dunnett.017. bDunnett T3 Test–-corrected level of significance at $P < .05$.

Table 3. Comparisons of the Ocular Vestibular Evoked Myogenic Potential Responses Between the Low Vision Group and the Control Group

oVEMP	PWLV			Control			PWLV vs Control	
	X	M	SD	X	M	SD	Test statistic	*P*
Right N10 Latency	9.84	9.67	0.82	9.41	9.67	0.92	402.50[U]	.32
Right P16 Latency	13.93	14.33	0.82	13.66	14	1.47	434.500[U]	.58
Right N1P1 Latency	4.05	4	1.62	4.4	4.33	1.28	419.500[U]	.45
Right N1P1 amplitude	21.56	18.59	14.2	20.57	17.6	13.08	449.000[U]	.73
Left N10 Latency	9.74	9.67	1.19	9.29	9.67	1	445.500[U]	.31
Left P16 Latency	14.12	14.67	1.77	13.44	13.67	1.67	1.519[t]	.13
Left N1P1 Latency	4.38	4.33	1.35	4.19	4.33	1.29	0.537[t]	.59
Left N1P1 amplitude	17.98	14.51	12.54	21.01	17.47	12.19	425.500[U]	.2
Asymmetry ratio between the ears	0.2	0.17	0.12	0.2	0.19	0.14	498.500[U]	.98

PWLV, persons with low vision.
[U]Mann–Whıtney *U* test-corrected level of significance at $P < .05$.
[t]Independent.05. Independent samples *t*-test-corrected level of significance at $P < .05$.

compensate for the loss of vision, blind people use other senses more through a compensation mechanism, and it is thought that in this situation, the vestibular system is activated more, and the VOR mechanism could be more developed.[2] The contrasting view is that VOR can generally be expected to be less effective as blind individuals have no access to visual information. As a result of this lack of visual feedback, it can be considered that the function of VOR may be limited. According to the literature, a significantly reduced VOR gain has been largely associated with vestibulopathy.[13,14] To investigate these 2 different conditions, VOR was evaluated in these individuals using vHIT in this study.

Jha et al[7] evaluated VOR in visually disabled individuals using vHIT. As a result of vHIT applied to 23 healthy subjects and 19 subjects with vision loss, all in the 18-40 years age range, abnormal VOR gains were determined in all the semicircular canals. Similarly, in the current study, the VOR gains were observed to be significantly low in the bilateral low vision and bilateral blind groups ($P < .05$). The application of vHIT was made to the current study control group in the same way as in the above-mentioned study: under the three conditions of darkness, daylight with no target, and as the classic method. The aim of using vHIT in darkness and in daylight with no target was to experimentally mimic the low vision group and the blind group. Thus, it was aimed to examine the change in VOR gains in healthy individuals when there was no visual input. The condition of daylight and no target was to replicate the condition of the low vision group and the condition of complete darkness was to replicate complete blindness to be able to examine how effective the VOR mechanism was in individuals with healthy vision when there is partial or no visual input.

The study results showed that the VOR gains were significantly low in both conditions of darkness and daylight with no target ($P < .05$). These results were consistent with the findings of Jha et al[7] In light of these results, vision seems to be of importance to the balance system. At the same time, it was observed that there was no complete absence of VOR, but a significant decrease in individuals with vision loss.

Magliulo et al[15] evaluated the vestibular system with cVEMP, oVEMP, vHIT, and the caloric test in 16 patients diagnosed with

Table 4. Comparisons of the Cervical Vestibular Evoked Myogenic Potential Responses Between the 3 Groups

cVEMP	PWB			PWLV			Control			PWLV vs Control	
	X	M	SD	X	M	SD	X	M	SD	Test statistic	*P*
Right P13 Latency	16.94	16.67	4.07	15.17	15.32	1.5	15.43	15.33	1.61	3.995[KW]	.13
Right N23 Latency	26.09	25.67	5.5	24.85	25.33	3.28	26.4	26.67	1.95	8.292[KW]	**.02***
Right N1P1 Latency	9.15	9.33	2.78	9.68	9.67	3.18	10.93	11	1.63	9.351[KW]	**.01***
Right N1P1 amplitude	59.07	56.26	44.64	95.98	64.32	63.32	124.97	100.4	81.23	10.152[KW]	**.01***
Left P13 Latency	16.17	15.33	4.23	16.03	15.67	1.6	15.45	15.33	1.46	1.261[KW]	.53
Left N23 Latency	26.97	26.33	5.4	26.18	26	3.2	26.24	26	2.2	0.334[KW]	.85
Left N1P1 Latency	10.74	11	2.37	10.06	10.5	3	10.81	10.67	2.16	0.763[KW]	.47
Left N1P1 amplitude	67.3	56.58	64.67	102.17	68.57	65.56	155.22	116.7	137.66	14.116[KW]	**.01***
Asymmetry ratio between the ears	0.26	0.26	0.17	0.19	0.18	0.17	0.24	0.2	0.16	2.424[KW]	.3

cVEMP, cervical vestibular evoked myogenic potential; PWB, persons with blindness; PWLV, persons with low vision.
[KW]Kruskal–Wallis test-corrected level of significance at $P < .05$.

retinitis pigmentosa. A cVEMP response could not be obtained in only 1 patient, and patients with total vision loss were not included in the study as vHIT could not be performed. The patients from whom a response was obtained were not compared with a healthy group. In the current study, an oVEMP response was not obtained from the bilateral blind group.

In another study by Magliulo et al,[16] cVEMP, oVEMP, and vHIT tests were used in the evaluation of the vestibular system of 15 patients diagnosed with Usher syndrome. As vHIT could not be able to be performed on patients with total vision loss, they were not included in the study. There was a history of at least 1 vertigo attack in 12 patients and no such history in 3. Of the 15 patients, a cVEMP response was obtained in 8, but there were no comparisons with a healthy control group.

When performing vHIT in the current study, to be able to select the pupil more clearly in some of the bilaterally blind subjects, a band was applied to the eyelid and as the ability to see was lost, commands were given verbally and by touching the right or left regions of the goggles. In the low vision group, vHIT could be performed with standard instructions. Bayram et al[17] investigated the effect of vision loss on oVEMP responses by examining and comparing the oVEMP responses of 31 individuals with unilateral blindness and 25 healthy control subjects. In 29 of the 31 unilaterally blind individuals, an oVEMP response was obtained from the blind side. When compared with the healthy subjects, no significant difference was determined in respect to latency, amplitude, and the asymmetry ratio. The current study results support the findings of that study. That oVEMP was obtained demonstrates that the oVEMP pathway (the utricle, superior vestibular nerve, vestibular nuclei, and VOR afferents) was working without problems, which is necessary for the stimulation of the superior vestibular nerve and VOR in the anterior and lateral planes. The fact that there was a comparable VOR gain in the low vision group and the healthy control group in the condition of simulated vision loss suggests that the absence of vision may not completely eliminate VOR. Ghahraman et al[18] used the cVEMP test to evaluate the vestibular system in 20 individuals with late onset vision loss and 20 healthy subjects. The results of the study showed no significant difference between the 2 groups with respect to the parameters of P13 and N23 latency values, amplitude, asymmetry ratio, and cVEMP threshold. It was recommended that the cVEMP test could be appropriate for the evaluation of vestibular function in visually disabled individuals. In addition, it can be said that there is healthy sacculo-collic pathway functioning in individuals with late onset vision loss.

When the current study results were examined in terms of the cVEMP responses of the bilateral low vision group and the control group, there was observed to be a significant shortening was observed only in the N23 latency and N1P1 latency values obtained from the right ear. Additionally, between the bilateral blind group and the control group, there was observed to be a significant shortening and decrease were observed in the N1P1 latency and N1P1 amplitude values obtained from the right ear, as well as in the N1P1 amplitude values obtained from the left ear. The absence of a significant result in this study was attributed to the variation in cVEMP findings from ear to ear. There is a need for further studies with larger samples to reach more accurate results.

CONCLUSION

The results of this study demonstrated that although VOR is significantly reduced in individuals with vision loss, it is not completely eliminated. The vHIT can be used to evaluate the functions of all the semicircular canals in individuals with vision loss. However, there is a need for the development of normative data in the visually impaired to make more accurate comparisons when evaluating the vestibular system in individuals with vision loss who have complaints related to balance. Further studies on vHIT application in individuals with vision loss who have a vestibular disorder are necessary. The study results also showed that a lack of visual cues decreased the VOR gain when vHIT was applied to healthy subjects under conditions of simulated blindness and low vision.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Başkent University (Approval No: KA22/219, Date: December 28, 2022).

Informed Consent: Written and verbal informed consent was obtained from all study participants who agreed to take part in the study.

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