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RESEARCH ARTICLE

EFFECTS OF GAZE POSITION ON OCULAR VESTIBULAR EVOKED MYOGENIC POTENTIAL (oVEMP)

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ABSTRACT

Purpose: To compare ocular vestibular evoked myogenic potential (oVEMP) responses obtained with superomedial and oblique gaze positions.
Material and Methods: The oVEMP test was applied in 59 healthy subjects at superomedial, right oblique, and left oblique gaze positions. Stimuli were presented at 110 dB nHL with a frequency of 500 Hz. oVEMP responses were recorded via electrodes placed on the lower eyelids.
Results: Higher N1-P1 amplitudes were obtained in oblique gaze positions in the stimulated ear direction compared to the superomedial position ($p<0.05$). The asymmetry values obtained in the superomedial gaze position were lower than those obtained in oblique gaze positions ($p<0.05$). Superomedial and oblique gaze positions had no effect on the N1, P1, and N1-P1 latencies of the waves obtained from the right ear, left ear, and both ears ($p>0.05$).
Conclusion: Superomedial and oblique gaze positions affect oVEMP waves. In patients in whom vestibular hypofunction is suspected, it is recommended to control oVEMP responses in oblique gaze positions as well as in superomedial gaze positions in the evaluation of the residual vestibular functions.

Keywords: oVEMP, gaze, extraocular musces

INTRODUCTION

The peripheral vestibular system includes the vestibular nerve, semicircular canals (SCCs), and otolith end organs (utricle and saccule). Otolith organs, which consist of the utricle and saccule, allow the perception of linear acceleration of the head as well as the perception of the gravity (1). Saccule and utricle functions are assessed with the vestibular evoked myogenic potential (VEMP) test (2). VEMPs are vestibular labyrinth-derived electromyographic responses induced by sound, vibration, or electrical stimulation (3). It was divided into cervical VEMP (cVEMP) and ocular VEMP (oVEMP). c-VEMP is recorded through the sternocleidomastoid muscle (SCM) to assess the function of the saccule and inferior vestibular nerve and tests the vestibulo-colic reflex (4). oVEMP is recorded through the contralateral inferior oblique muscle to evaluate the function of the utricle and superior vestibular nerve and tests the otolith-ocular reflex (5). oVEMP is

Table 1. Comparison of right ear responses between superomedial, right oblique and left oblique gaze positions

Variable		**Right Ear Responses**		
		Mean+SD (M)	***Test[a]***	***p Value***
N1 Latency (ms)	*Superomedial gaze*	9,82 ± 0,77 (9,7)	5,584	0,061
	Right oblique gaze	9,74 ± 0,75 (9,7)		
	Left oblique gaze	10 ± 0,68 (9,8)		
P1 Latency (ms)	*Superomedial gaze*	15,28 ± 0,85 (15,1)	5,033	0,081
	Right oblique gaze	15,17 ± 0,92 (15,2)		
	Left oblique gaze	15,48 ± 0,88 (15,5)		
N1-P1 Interlatency (ms)	*Superomedial gaze*	5,44 ± 0,66 (5,5)	0,272	0,873
	Right oblique gaze	5,4 ± 0,63 (5,4)		
	Left oblique gaze	5,49 ± 0,8 (5,4)		
N1-P1 Amplitude (mV)	*Superomedial gaze*	8,6 ± 3,67 (8,2)	***22,896***	***<0,001****
	Right oblique gaze	10,97 ± 4,42 (10,7)		
	Left oblique gaze	7,44 ± 3,74 (6,4)		

SD: Standard Deviation, M; Median, a; Kruskal Wallis Test Value, *p<0.05 shows statistically significant difference between groups.

recorded via electrodes placed around the eyes. The oVEMP consists of two wave peaks: negative and positive. The negative wave peak has a latency time of about 10 ms and is defined as the N1 wave. The positive wave peak has a latency time of about 15 ms and is defined as the P1 wave (6).

Eye movements occur as a result of the active functioning of the extraocular muscles. Because the extraocular muscles contract faster than other voluntary muscles, they respond quickly to sensory reflexes. In particular, reflexes originating via vestibular stimulation have an important role in determining the spatial position of the eyes by means of extraocular muscles, and in the occurrence of eye movement appropriate for stimulation (6). Extraocular muscles are divided into two main groups as rectus and oblique. The basic function of the rectus muscles is the movement of the eye to the right or left on the horizontal plane and up or down on the vertical plane. The main function of the oblique muscles is to provide torsional movements allowing movements inward or outward (7). In the oVEMP test, the patient is given an upward gaze position and a response is obtained from the inferior oblique muscle of the contralateral eye. In the oVEMP test, it is thought that the wave amplitude to be obtained with the oblique gaze, which will provide maximum stimulation of the inferior oblique muscle, will be higher than the wave amplitude obtained with the upward gaze only in the vertical plane. Therefore, in order to determine that there is no oVEMP response, it is necessary to check the right and left oblique gazes as well as the maximum superomedial gaze. Testing in these gaze directions can be considered in vestibular hypofunction investigations to determine residual function.

There are limited studies in the literature about the effect of gaze position on the parameters of oVEMP waves and the most ideal gaze position (8-10). In this study, it was aimed to compare the wave parameters obtained with the oblique gaze, which will provide maximum stimulation of the inferior oblique muscle,

Table 2. Comparison of left ear responses between superomedial, right oblique and left oblique gaze positions

Variable		Left Ear Responses		
		Mean+SD (M)	**Test[a]**	**p Value**
N1 Latency (ms)	Superomedial gaze	9,89 ± 0,68 (9,8)	1,307	0,520
	Right oblique gaze	9,97 ± 0,66 (10,0)		
	Left oblique gaze	9,89 ± 0,76 (9,7)		
P1 Latency (ms)	Superomedial gaze	15,17 ± 1,02 (15,1)	2,955	0,228
	Right oblique gaze	15,41 ± 0,97 (15,5)		
	Left oblique gaze	15,41 ± 0,87 (15,5)		
N1-P1 Interlatency (ms)	Superomedial gaze	5,24 ± 0,75 (5,3)	2,386	0,303
	Right oblique gaze	5,38 ± 0,94 (5,3)		
	Left oblique gaze	5,48 ± 0,7 (5,4)		
N1-P1 Amplitude (mV)	Superomedial gaze	8,98 ± 3,58 (8,2)	**25,370**	**<0,001***
	Right oblique gaze	7,57 ± 3,4 (6,8)		
	Left oblique gaze	11,04 ± 4,22 (9,9)		

SD: Standard Deviation, M; Median, a; Kruskal Wallis Test Value, *p<0.05 shows statistically significant difference between groups

and those obtained by looking up in the vertical plane during oVEMP recording.

MATERIAL AND METHODS

Subjects

The research was carried out prospectively in the Audiology Unit of the Otorhinolaryngology Polyclinic of a University Hospital between Nov 2020 and Jan 2021. The sample size of the study; It was determined as 30 with a 97% confidence interval and 80% ability to represent the universe using power analysis. Fifty-nine healthy subjects were included in the study (42 females, 17 males; mean age 24.01 ± 4.47 years). Complaints of dizziness and imbalance, conductive hearing loss, otologic diseases, neurological diseases, and eye muscle problems were set as exclusion criteria. Approval was obtained from Inonu University Institute of Health Sciences Non-Invasive Clinical Research Ethics Committee (Date: 07.04.2020, Number: 2020/629) and from all individuals participating in the study.

Stimuli and Recording Parameters

oVEMP test was performed with Neuro-Audio/Neurosoft (version 2010) device. Stimuli were administered through ER-3A insert headphones at 110 dB nHL with a frequency of 500 Hz. Two hundred sweeps were given to each ear separately. In order to verify the accuracy of the waves obtained, double traces were recorded from each ear. Responses were recorded through electrodes placed on the lower eyelid. The active electrodes were approximately 1 cm below the right and left lower eyelids and the reference electrodes were placed 1 cm below the active electrodes. The ground electrode was placed on the forehead. Electrode impedances were kept below 5 kΩ. In response to the stimuli, N1 and P1 waves were obtained contralaterally to the ear tested. In measurements made with the device, the value recorded for one direction does not affect the value obtained from other directions. For example, the "right oblique" measurement value of a patient is calculated independently of the "superomedial" or "left oblique" measurement values. Therefore, the data obtained for 3 different directions in each patient are independent from each other.

Experiment Setup

The subjects were tested for oVEMP in three different gaze positions. The tests were carried out with the

Table 3. Comparison of asymmetry values in superomedial, right oblique and left oblique gaze positions

Variable	Group	Mean+SD (M)	Test Value	p Value
Asymmetry (%)	Superomedial gaze	10,49 ± 9,1 (7,9)	**32,518**	**0,001***
	Right oblique gaze	20,68 ± 13,96 (17,8)		
	Left oblique gaze	24,21 ± 15,82 (20,4)		

SD: Standard Deviation, M; Median, *p<0.05 shows statistically significant difference between groups

subjects sitting upright. Three different fixed targets were set in the middle and on the right and left, 1.5 meters away from the subjects, and 30° above the eye level. First, recordings were taken in the upward gaze position. The subjects were told to direct their gaze to the fixed target in the middle. Separate recordings were taken from both ears during the stimuli was given while the subjects were looking up. They were then instructed to direct their gaze to the fixed target on the right. Separate recordings were taken from both ears during the stimulation given during right and upward torsional gaze. Finally, the subjects were told to direct their gaze to the fixed target on the left. Separate recordings were taken from both ears during the stimulation given during left and upward torsional gaze. N1 wave latency, P1 wave latency, N1-P1 interlatency, N1-P1 wave amplitude obtained from three different gaze positions and asymmetry value representing the amplitude differences of the waves obtained from the right and left ears were compared.

Statistical Analysis

Data analysis was carried out with the SPSS (Statistical Program in Social Sciences) 25.0 package program. The normal distribution of the data was checked with the Kolmogorov Smirnov Test (11). The significance level was taken as 0.05 for the comparison tests. The Kruskal Wallis test was used as the measurements obtained for three different directions (right oblique, left oblique, superomedial) are independent of each other. In order to determine from which groups the statistical difference arise in the groups with a difference, paired comparisons (p <0.05) were performed using the Mann-Whitney Test. At this stage of the analysis, the p value will increase due to the increase in the number of comparisons, so the Bonferroni corrected p value is used and it is calculated with "(0.05/paired comparison)" (12). Since the number of groups in the study was 3 (superomedial, right oblique, and left oblique) and the number of comparisons was 2, it was calculated by $\binom{3}{2} = 3$, αBD = 0.05 / 3 = 0.017. After the Kruskal-Wallis test, the p values obtained by the Mann-Whitney test were compared with 0.017, and thereby the results were determined.

Demographic Information

Of the 59 participants included in the study, 42 (71.2%) were women and 17 (28.8%) were men. The average age of the participants was 24.01 ± 4.47 years.

RESULTS

The comparison of the N1, P1, N1-P1 interlatency and N1-P1 amplitudes of oVEMP response parameters from the right ear between gaze positions is shown in Table 1.

There was no statistically significant difference between the superomedial, right oblique and left oblique gaze positions of the N1, P1 and N1-P1 interlatency parameters of o-VEMP wave responses from the right ear (p>0.05, Table 1). A statistically significant difference was found between the N1-P1 amplitudes of o-VEMP wave responses from the right ear (p<0.05, Table 1).

The comparison of the N1, P1, N1-P1 interlatency and N1-P1 amplitudes of o-VEMP response parameters taken from the left ear between gaze positions is shown in Table 2.

There was no statistically significant difference between the superomedial, right oblique and left oblique gaze positions of the N1, P1 and N1-P1 interlatency parameters of oVEMP wave responses from the left ear (p>0.05, Table 2). A statistically significant difference was found between the N1-P1 amplitudes of o-VEMP wave responses from the left ear (p<0.05, Table 2).

The comparison of the asymmetry value, which represents the difference between the wave amplitudes of the responses from the right and left

Table 4. Comparison of gaze positions in values with statistically significant difference

Variable		First Group	Second Group	Test[b]	p Value
N1-P1 Amplitude (mV)	***Right Ear Responses***	*Superomedial gaze*	*Right oblique gaze*	***-3,06***	***0,002****
			Left oblique gaze	-2,097	0,036
		Right oblique gaze	*Left oblique gaze*	***-4,54***	***0,001****
	Left Ear Responses	*Superomedial gaze*	*Right oblique gaze*	-2,468	0,014
			Left oblique gaze	***-2,888***	***0,004****
		Right oblique gaze	*Left oblique gaze*	***-4,858***	***0,001****
Asymmetry (%)		*Superomedial gaze*	*Right oblique gaze*	***-4,422***	***0,001****
			Left oblique gaze	***-5,283***	***0,001****
		Right oblique gaze	*Left oblique gaze*	-1,095	0,273

b: Mann Whitney Test Value, *p<0.017 shows statistically significant difference between groups.

ears, between the superomedial, right oblique and left oblique gaze positions is shown in Table 3.

A statistically significant difference was found between the superomedial, right oblique and left oblique gaze positions of the asymmetry value, which represents the difference between the wave amplitudes of the responses from the right and left ears (p<0.05, Table 3).

Pairwise comparisons were made with Mann-Whitney test after Kruskal Wallis test in order to determine which gaze positions differ among the parameters with difference in superomedial, right oblique and left oblique gaze positions, and Bonferroni corrected significance value was taken as 0.017 (Table 4).

A statistically significant difference was found between the superomedial gaze and the right oblique gaze, and between the right oblique and left oblique gaze in the N1-P1 amplitude value of the responses received from the right ear (p<0.017, Table 4). There was no statistically significant difference between the superomedial gaze and the left oblique gaze in the N1-P1 amplitude values of the responses received from the right ear (p>0.017, Table 4).

A statistically significant difference was found between the superomedial gaze and the left oblique gaze, and between the right oblique and left oblique gaze in the N1-P1 amplitude value of the responses received from the left ear (p<0.017, Table 4). There was no statistically significant difference between the superomedial gaze and the right oblique gaze in the N1-P1 amplitude values of the responses received from the left ear (p>0.017, Table 4).

A statistically significant difference was found between the superomedial gaze and the right and left oblique gaze in the asymmetry measurement value (p<0.017, Table 4). There was no statistically significant difference between the left oblique and right oblique gaze in the asymmetry measurement value (p>0.017, Table 4).

DISCUSSION

oVEMP is recorded by means of electrodes placed around the eyes and the stimulation of the ipsilateral otolith organ (utricle) and the contralateral extraocular muscle with sound stimulation (13). Many of the extraocular muscles are associated with otolith stimulation. However, oVEMP is thought to originate from the inferior oblique muscle due to its anatomical proximity to the recording electrodes placed below the eyes (14). Although the total activity of a few extraocular muscles is effective due to the area covered by electrodes in oVEMP recordings, the muscle that is tonically active according to the gaze position plays an important role (10). In clinics, the oVEMP test is performed in the superomedial gaze position. However, in the oVEMP test, it is expected that the wave amplitude to be obtained with the oblique gaze, which will provide the maximum stimulation of the inferior oblique muscle, will be higher than the wave amplitude that can be obtained only by looking up in the vertical plane. In addition, its effects on latencies are also of interest. Therefore, we aimed to investigate the effects of gaze position on oVEMP.

When the N1, P1, and N1-P1 latencies of the waves obtained from both right, left, and all ears were compared between gaze positions in our study, no statistically significant difference was found. Similarly, Govender et al. (2009) compared the waves obtained in the horizontal plane abduction and adduction gaze positions, and they did not report a difference between latencies (8). In addition, in the same study, no difference was found between latencies in changes in body and head positions. In another study, Chihara et al. (2007) found no difference in latencies when they compared the waves obtained in superomedial, superolateral, inferolateral, inferomedial, and neutral gaze positions in healthy individuals (9). Contrary to the present study, Govender et al. (2009) stated that they observed differences between latencies when they compared the waves obtained from superomedial and inferomedial gazes in the vertical plane (8). In another study, Rosengren et al. (2013) compared the waves obtained in superomedial, neutral, and inferomedial gaze positions, and stated that the wave latencies in the inferomedial position were significantly higher compared to those obtained in the superomedial and neutral gaze positions (10). Additionally, Huang et al. (2012) also found a significant latency in N1, P1, N1-P1 waves obtained with the eyes closed (15). In a different study in the literature, Weber et al. (2012) stated that in oVEMP waves recorded with concentric needle electrodes in healthy individuals, if the first negative peak is of the inferior oblique origin, it is approximately 10 ms, and if it originates from the inferior rectus, it is approximately 15 ms. They stated that the motor unit activity of the muscles was quite synchronized, but the inferior rectus muscle functioned with a short latency. In their study, the use of concentric needle electrodes yielded more clear information about the firing of the motor units of the muscles (16). Thus, their results supported the outcome that both muscles interacted in the oVEMP test, but that the N1 potential was affected by inferior oblique muscles more. In addition, the literature has supported the outcome that latency in the inferomedial gaze position is caused by the inferior rectus muscle, which plays a role in this position.

Based on the findings in the literature, the differences in the latencies of the waves obtained in the vertical plane and in the superomedial and inferomedial gaze positions of the eye suggest that different extraocular muscle groups and different motor units play a role. For this reason, it is noteworthy that there may be differences in the neural arc followed during the formation of the wave. In addition, based on the present results and the findings in the literature, the fact that no difference has been observed in the latencies of the waves between the right oblique, superomedial, left oblique gaze positions, and those obtained in adduction, abduction, and superomedial gaze positions in the horizontal plane suggests that the neural arc followed by the wave may be similar.

In the present study, between the gaze positions, a statistically significant difference was found in terms of the N1-P1 amplitudes of the waves obtained from both right and left ears. N1-P1 amplitudes obtained from the ear on the gaze direction in oblique gaze positions were higher than those obtained from other gaze positions. Studies in the literature have shown that differences in gaze positions have an effect on amplitudes (8-10). Chihara et al. (2007) examined oVEMP recordings in superomedial, superolateral, inferolateral, inferomedial, and neutral gaze positions in healthy individuals. The amplitudes in the superomedial and superolateral gaze positions were higher than those in other gaze positions (9). Contrary to the present study, Chihara et al. (2007) obtained similar amplitudes from superomedial and superolateral gaze positions (9). Rosengren et al. (2005) and Govender et al. (2009) also found that the amplitudes of the oVEMP waves they obtained at the superomedial gaze position were higher than those obtained at the neutral gaze (8, 17). Govender et al. (2009) also stated that amplitudes increase with the increasing angle of gaze in the superomedial gaze position (8). They also reported that there were no significant differences in amplitudes obtained in different head positions (8). Rosengren et al. (2013) examined the oVEMP recordings in the superomedial, neutral, and inferomedial gaze positions, and stated that they obtained the highest amplitude in the superomedial gaze (10). In addition, in the same study, electrode displacements were made by keeping the gaze fixed. The displacement of the electrodes caused differences in the amplitudes of the waves obtained (10). Additionally, Huang et al. (2012) stated that the N1-P1 amplitude obtained in the eyes open position was higher than that obtained in the eyes closed position (15).

In the present study, the larger amplitudes of the waves obtained in the oblique gaze support both the stimulation of the inferior oblique muscle in this movement and the proximity of the inferior oblique muscle to the recording electrode. At the same time, it supported the outcome that the change in the amplitude of the waves obtained by the gaze position was due to the increase in the tonic activity of the eye muscles. Similarly, in the cVEMP test, we can see the increase in the amplitude of the waves obtained by the increase of the tonic activity of the SCM (18).

In the present study, a statistically significant difference was found between the asymmetry values of the waves obtained from different gaze positions. Contrary to our study, Huang et al. (2012) found no significant difference between asymmetry values, which were evaluated in eyes closed and eyes open without changing the gaze position (15). Similar to the present study, Govender et al. (2009) stated that abduction and adduction gaze positions had a significant effect on amplitudes (8). In addition, it was stated that the wave obtained in the adduction gaze position had a slightly larger amplitude than the wave obtained in the abduction gaze position (8). This finding supports the larger amplitudes obtained from the ears on the direction of gaze during oblique gaze position in the present study. The present study suggests that abduction and adduction movements that occur in oblique gaze positions create an asymmetrical difference.

CONCLUSION

As a result, it is seen that differences in gaze positions resulted in significant changes on oVEMP. In clinics where oVEMP tests are performed, the gaze position should be standardized and used in the same way for each patient. The increases in amplitude obtained in the oblique gaze position in the present study draw attention to the fact that it can be used for the evaluation of residual vestibular functions in cases where vestibular hypofunction is considered. Before it is reported in clinics that “oVEMP responses cannot be obtained”, it is recommended to check the right and left oblique gaze in addition to the superomedial gaze.

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