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Outcomes of cVEMP and oVEMP in Individuals with Tinnitus and Normal Hearing

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ABSTRACT

Purpose: The purpose of the present study is to find the functions of vestibular reflexes in individuals' with normal hearing and tinnitus, to identify vestibular dysfunctions earlier, and helps with the management of the same.

Method: The present study aimed to administer cVEMP and oVEMP to all the participants having a normal hearing with tinnitus (experimental group) and without tinnitus (Control group) and compared p13, n23 latencies and peak-to-peak amplitude of cVEMP; n10, p15 latencies of oVEMP and peak-to-peak amplitude between two groups and within tinnitus group.

Results: The present study stated that there is no statistically significant difference seen in cVEMP except n23 latency of bilateral tinnitus than control group. However, there is statistically significant difference in left ear p15 latency, left ear peak-to-peak amplitude, bilateral peak-to-peak amplitude between the two groups and Right Vs Left ear peak-to-peak amplitude in within the tinnitus group was seen in oVEMP. T-test was used to compare the latencies of p13, n23, and peak-to-peak amplitude of cVEMP and n10, p15 latencies and peak-to-peak amplitude of oVEMP between the experimental and control group and within the tinnitus group.

Conclusion: There is no significant difference seen in cVEMP except n23 latency of bilateral tinnitus than control group and However, there is statistically significant difference in left ear p15 latency, left ear peak-to-peak amplitude, bilateral peak-to-peak amplitude between the two groups and Right Vs Left ear peak-to-peak amplitude in within the tinnitus group was seen in oVEMP and the current study concluded that the significant results with several parameters and no significant results with other parameters in cVEMP and oVEMP recording might be Presymptomatic tinnitus is regarded to occur in ears with normal hearing and abnormal VEMP, while asymptomatic tinnitus may occur in ears with normal VEMP. Tinnitus may be the first signs of secondary or delayed endolymphatic hydrops. If this is demonstrated to be accurate, we should anticipate that such patients will gradually develop other endolymphatic hydrops symptoms like SNHL and clinical vestibular dysfunction.

Keywords: cVemp, oVemp, Tinnitus, Normal hearing, Vestibular function.

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INTRODUCTION

The ringing sensation in the ears without the presence of any external sound is defined as tinnitus[1]. The prevalence of tinnitus increases with age, the prevalence of tinnitus in children was 5.24% and 16.81% in older individuals[2]. Tinnitus occurs in 1 out of every 200 adults in everyday life[3]. The generation of tinnitus is not limited to the peripheral auditory system[4]. Tinnitus is broadly classified into subjective and objective tinnitus[5-7]. Subjective tinnitus is only heard by individuals who have tinnitus, it occurs without any source in external and it is the experience of auditory sensation[8]. Subjective tinnitus is a buzzing, ringing, humming, blowing, or drum-like type that is caused by the perception of pure tones or frequency range of noise that are similar to white noise but have no discernible pattern of organization[9,10]. Subjective tinnitus can occur for a variety of reasons one of which is a malfunction of the vestibular system. Subjective tinnitus which majorly taught to be caused by a variety of problems with the physiological system of hearing[11]. Idiopathic tinnitus pathophysiology involves the manifestation of both the classic and non-classic auditory pathways. Objective tinnitus is perceived by individuals who have it and as well as others too, it is initiated through internal biological activity in the human body[12,13]. Tinnitus has been described as a potentially debilitating symptom that can be distressing to the person who suffers from it, especially if hearing loss is present[12-14]. This symptom is commonly associated with noise exposure, aging, and hearing loss although it can occur in a person who has normal hearing, Tinnitus may also be caused by other risk factors such as head trauma, hypertension, arthritis, smoking, obesity, and alcohol. However, the majority of the time, tinnitus is associated with conditions such as endolymphatic hydrops, migraine-induced vestibular pathology, vestibular schwannoma, otosclerosis, labyrinthitis, ototoxicity, multiple sclerosis, meningioma, and stroke[15,16]. Tinnitus is a common disorder that affects a large percentage of the population and causes significant morbidity, as well as disrupting sleep, attention, emotional equilibrium, and patients' social lives. Vitamin A and B deficits have also been found to cause tinnitus[15-20]. Tinnitus is commonly associated with vestibular dysfunctions, hypertension, and vertigo, fullness in the ears, with and without hearing loss. However, earlier literature mentioned that cochlea and vestibular systems work as a unit so there might be a relationship between sacculo-colic and utriculo-ocular reflexes and tinnitus in individuals with normal hearing.

Only limited research was done using VEMPs on the individual with normal hearing and tinnitus[21]. Subjective tinnitus can occur anywhere in the auditory system and it increases perceived sound through an unknown mechanism[22]. Admis et al, did a study using VEMP in individuals with normal hearing and tinnitus, the results revealed that there was no significant difference seen in PTA, SRT, WDS, UCL, TDQ, immittance audiometry, oVEMP, and cVEMP between normal hearing without tinnitus and normal hearing with tinnitus. Garcia et al.[23], carried out a neuro otological test apart from the VEMP test on individuals with normal hearing who had tinnitus. 17 patients were examined with neuro otological evaluation such as stance and gait, cerebellar examination, audiological evaluation such as caloric test (Fitzgerald and hall pike techniques), electronystagmography, and evaluation of positional and optokinetic nystagmus. The caloric test showed right canal paresis and gait to be normal. Romberg test was sensitive towards the tinnitus side and unilateral canal paresis was observed in the tinnitus ear. Barany's pointing test was abnormal and the author concluded that tinnitus was a clinical manifestation of the cochlear vestibular lesion. Kadan et al.[24], did a study on vestibular ocular reflex in normal-hearing individuals who had tinnitus, excluding the VEMP test, Video head impulse test was found to exhibit a lower vestibular ocular reflex in tinnitus ear. Weshahy et al.[25], did a study on unilateral subjective idiopathic tinnitus who had normal hearing was assessed with pure tone audiometry, immittance audiometry, speech audiometry, auditory brainstem response, vestibular evoked myogenic response, and video nystagmography test. Results revealed no statistically significant difference between P1, N1 amplitude, and latency in both tinnitus ears. However, a statistical difference was observed in the asymmetry ratio, oculomotor test, and caloric test between the tinnitus ear and normal ear. Only a few studies of cVEMP and oVEMP were carried out among individuals with normal hearing and tinnitus and the results are contraindicating between the studies and/or age range is a difference. Even though it is important to know the relationship between tinnitus and functions of the vestibular system, it helps for earlier identification of vestibular dysfunction and management purpose among individuals with normal hearing and tinnitus. Hence the present study aimed to evaluate the sacculo-colic and utriculo-ocular reflexes by cVEMP and oVEMP among individuals with normal hearing and tinnitus.

METHODS

Participants: The present study was conducted at SRM Medical college hospital and Research Centre, SRM Institution of Science and Technology, Chennai. The SRMIST scientific committee and the ethical committee approved the study. The authors declare that all the processes contributing to this work adhere to the relevant institute's ethical standards Reference Number 2210/IEC/2020. In the present study 50 participants have included out of those 25 individuals were normal hearing without tinnitus (control group) and 25 individuals were normal hearing with tinnitus (experimental group) in the age range of 18 to 48 years Mean and standard deviation for age range in the control group is (24.1 $\pm$ 2.4) and for case, the group is (29.2 $\pm$ 5.3). However, the present study was followed inclusion and exclusion criteria for the participants to participate in the study, common inclusion criteria for both control and experimental groups were

individuals in the age range of 18 to 48 years, with no history or complaint of middle ear pathology, head trauma, neurological problems. Individuals with normal hearing (PTA ≤ 15dB) fall under the control group and individuals with normal hearing (PTA ≤ 15dB) and tinnitus fall under the experimental group. The exclusion criteria were individuals with hearing loss (PTA>15dBHL), less than 18 years and greater than 48 years of age, individuals with middle ear pathology, head trauma, and neurological problem.

Procedure: In the present study all the participants underwent basic audiological tests such as pure tone audiometry (Dual channel Inventis piano audiometer with TDH 39 transducer), the subject's pure tone hearing thresholds were within the normal range, i.e., 15 dBHL[26], for octave frequencies ranging from 250 to 8000Hz for AC and 250 to 4000 Hz for BC. Immittance testing such as tympanometry & acoustic reflex test (GSI Tympstar pro), The immittance audiometer was used to evaluate each subject's middle ear status to rule out any middle ear pathology that could affect both c-VEMP and oVEMP findings and cause the results to vary, Distortion Product Oto Acoustic Emissions (DPOAE) was used to evaluate the functioning of outer hair cells and Auditory Brainstem Response (ABR) to ensure hearing sensitivity within normal limits. However cervical Vestibular Evoked Myogenic Potential (cVEMP) and ocular Vestibular Evoked Myogenic Potential (oVEMP) were carried out on all the participants. All the above-mentioned tests were carried out in the acoustically treated room and the ambient noise levels were well within the acceptable range. The electrode placement location was cleaned by a nuprep skin gel to attain adequate electrode impedances gold plated electrodes were used with the conduction paste and electrodes were placed with surgical plaster, During the recording of c VEMP and o VEMP absolute and inter-electrode impedance maintained was 5 k Ω and 3 k Ω correspondingly. The stimulus and acquisition parameters suggested in the earlier studies were used to record cVEMP and oVEMP[27-29]. The inverting electrode was placed on the sternoclavicular joint, the ground electrode was placed on the forehead and the non-inverting electrode was placed on 1/3 of the sternocleidomastoid muscle was activated in the sitting position by turning the head into the opposite to the test ear. However, to acquire oVEMP the non-inverting electrode was placed 1cm below the center of the eyelid and Inverting electrode was placed 3 cm below the center of the eyelid and the common electrode was placed on the forehead. The contralateral Inferior oblique muscle was activated by asking the participant to elevate their gaze by 30 to 35[30-32]. cVEMP and oVEMP were recorded using alternating polarity with tone burst stimuli at 500 Hz with 1ms rise/fall time and plateau of 2ms time were transmitted *via* standard insert earphones ER-3A at 125dB SPL. 5.1 Hz was used as the repetition rate as this frequency is the most efficient for evoking oVEMP which produced the highest signal-to-noise ratio and minimal inter-individual variability[33]. 200 EMG activity sweeps were recorded using a 64 ms epoch, including a10ms pre-stimulation (baseline) recording using a 1Hz–1000Hz bandpass filter. Regardless of the filter, the responses are always multiplied by 30,000. To avoid rejecting the natural high-amplitude myogenic potential, artifact removal is disabled. The display order was pseudo-random to avoid the effects of the order which can distort the results. Enough rest was given between the recordings to avoid muscle fatigue and unintentional blinking.

Measures: The peaks are marked as n10, p15 in oVEMP and p13, n23 in cVEMP. The parameters analyzed in this study are p13, n23 latencies, and peak-peak amplitude of cVEMP and n10, p15 latencies, and peak-peak amplitude of oVEMP were measured between the control group and experimental group and within the tinnitus group to find the differences.

RESULTS

The current study aimed to evaluate sacculo-colic and utriculo-ocular reflexes in individuals with tinnitus and normal hearing. Cervical vestibular myogenic potential and ocular vestibular myogenic potential were administered. The latency of both the cervical Vestibular Evoked Myogenic Potential (cVEMP) and ocular Vestibular Evoked Myogenic Potential (oVEMP) analysis were tabulated and the analysis was done using SPSS version 21.0. Descriptive statistics and inferential statistics (t-test) were used for the analysis of the results. The age range of participants was 18 to 48 years with the mean age for the control and tinnitus groups being 24.1 ± 2.4 and 29.2 ± 5.3years respectively. The total number of individuals recruited in the study was 25 healthy individuals who volunteered for the test in the control group and 25normal-hearing individuals with tinnitus in the case group. Out of 25 individuals with tinnitus 13 had tinnitus in the right ear and 8 had tinnitus in the left ear and 4 had tinnitus in both the ears.

The comparison of the measure of cVEMP: The mean, standard deviation and comparison of the p13, n23 latencies and the peak to peak amplitude of cVEMP using the independent sample t-test between the tinnitus and control group and within the tinnitus group (Right *Vs* Left ear & Unilateral (Rt+Lt) *Vs* Bilateral) was tabulated in table 1. It is evident that in the cVEMP when compared between the tinnitus and control group and within the tinnitus group (Right *Vs* Left ear & Unilateral (Rt+Lt) *Vs* Bilateral) no statistically significant difference was observed in the latencies (p13, & n23) and peak-to-peak amplitude, except n23 latency of individuals with bilateral tinnitus than control group.

To evaluate and compare the measure of oVEMP between the two groups: The mean, standard deviation and comparison of the n10, p15 latencies and the peak-to-peak amplitude of oVEMP using the independent sample t-test between the tinnitus and control group and within the tinnitus group (Right *Vs* Left ear & Unilateral (Rt+Lt) *Vs* Bilateral) was tabulated in table 2. It is evident

Table 1: cVEMP test results comparison.

Tinnitus Group (n=25)	Control Group (n=25)			
cVEMP Responses	**Mean (SD)**	**Mean (SD)**	**t**	**p – Value**
Right ear p13 (ms)	14.37 (1.09)	14.44 (1.60)	0.14	0.89
Right ear n23 (ms)	21.52 (2.04)	22.91 (1.76)	1.859	0.075
Right ear Peak to peak amplitude (μV)	181.93 (36.43)	190.09 (30.49)	0.619	0.542
Left ear p13 (ms)	14.37 (1.56)	14.26 (1.32)	-0.153	0.88
Left ear n23 (ms)	22.55 (1.14)	22.32 (1.96)	-0.287	0.78
Left ear Peak to peak amplitude (μV)	183.09 (31.99)	144.85 (41.97)	-2.049	0.06
Bilateral p13 (ms)	15.20 (0.90)	14.30 (1.64)	-1.358	0.196
Bilateral n23 (ms)	23.52 (1.61)	21.58 (1.49)	-2.505	0.025*
Bilateral Peak to peak amplitude (μV)	189.04 (23.22)	198.88 (19.26)	0.922	0.372
Unilateral (Rt+Lt) p13 (ms)	14.37 (1.25)	14.37 (1.47)	0.01	0.992
Unilateral (Rt+Lt) n23 (ms)	21.91 (1.79)	22.68 (1.81)	1.388	0.173
Unilateral (Rt+Lt) Peak to peak amplitude (μV)	182.37 (33.98)	172.85 (41..00)	-0.819	0.418
Right Vs Left ear p13 (ms)	14.37 (1.56)	14.37 (1.09)	-0.01	0.992
Right Vs Left ear n23 (ms)	22.55 (1.14)	21.52 (2.04)	-1.294	0.211
Right Vs Left ear Peak to peak amplitude (μV)	183.09 (31.99)	181.93 (36.43)	-0.074	0.942
Unilateral (Rt+Lt) Vs Bilateral p13 (ms)	14.90 (0.98)	14.37 (1.25)	-0.798	0.433
Unilateral (Rt+Lt) Vs Bilateral n23 (ms)	23.63 (0.96)	21.91 (1.79)	-1.847	0.078
Unilateral (Rt+Lt) Vs Bilateral Peak to peak amplitude (μV)	181.16 (27.22)	182.37 (33.98)	0.067	0.947

Table 2: oVEMP test results comparison.

Tinnitus Group (n=25)	Control Group (n=25)			
oVEMP Responses	**Mean (SD)**	**Mean (SD)**	**t**	**p – Value**
Right ear n10 (ms)	10.90 (0.657)	10.97 (0.96)	0.195	0.847
Right ear p15 (ms)	15.61 (0.675)	15.51 (1.44)	-0.226	0.823
Right ear Peak to peak amplitude (μV)	13.19 (4.13)	14.27 (8.01)	0.429	0.673
Left ear n10 (ms)	10.73 (0.50)	10.95 (0.84)	0.624	0.543
Left ear p15 (ms)	16.10 (0.563)	15.24 (0.62)	-2.914	0.011*
Left ear Peak to peak amplitude (μV)	17.31 (3.96)	10.74 (0.00)	-4.693	0.002*
Bilateral n10 (ms)	10.67 (0.66)	10.79 (0.67)	0.37	0.717
Bilateral p15 (ms)	15.88 (0.65)	15.30 (0.72)	-1.669	0.117
Bilateral Peak to peak amplitude (μV)	18.82 (4.44)	12.07 (1.57)	-4.053	0.001*
Unilateral (Rt+Lt) n10 (ms)	10.83 (0.59)	10.96 (0.90)	0.517	0.608
Unilateral (Rt+Lt) p15 (ms)	15.79 (0.66)	15.40 (1.18)	-1.318	0.195
Unilateral (Rt+Lt) Peak to peak amplitude (μV)	14.76 (4.46)	12.92 (6.45)	-1.074	0.289
Right Vs Left ear n10 (ms)	10.73 (0.50)	10.90 (0.65)	0.62	0.543
Right Vs Left ear p15 (ms)	16.10 (0.56)	15.61 (0.67)	-1.708	0.104
Right Vs Left ear Peak to peak amplitude (μV)	17.31 (3.96)	13.19 (4.13)	-2.249	0.037*
Unilateral (Rt+Lt) Vs Bilateral n10 (ms)	10.73 (0.64)	10.89 (0.75)	0.757	0.452
Unilateral (Rt+Lt) Vs Bilateral p15 (ms)	15.59 (0.73)	15.60 (0.96)	0.031	0.976
Unilateral (Rt+Lt) Vs Bilateral Peak to peak amplitude (μ V)	15.44 (4.74)	13.84 (5.55)	-1.021	0.312

that in the oVEMP when compared between the tinnitus and control group, statistically significant difference was observed for left ear p15 latency, left ear peak-to-peak amplitude, and individuals with bilateral peak-to-peak amplitude remaining parameters were no statistically significant difference and within the tinnitus group (Right *Vs* Left ear & Unilateral (Rt+Lt) *Vs* Bilateral) no statistically significant difference was observed in the latencies (n10, & p15) and peak-to-peak amplitude except Right *Vs* Left ear peak-to-peak amplitude.

DISCUSSION

Vestibular Evoked Myogenic Potentials are electro myographic responses elicited by sounds, vibration, or electrical stimulation in the vestibular labyrinth[34]. VEMP test is a clinical examination of the otolith organs, and linear acceleration sensors, and is related to reflex pathways[35]. In human's otolith organs are saccule and utricle (Colebatch & Halmagyi), cVEMP appears to be a reflection of saccular functions and o VEMP reflects the utricular functions[30,36]. A previous study reported that subjective tinnitus is a complex, heterogenous central nervous system disorder that affects not only the auditory pathway but also non auditory areas such as the pre frontal cortex, para hippocampus, amygdala, insula, and cerebellum[37]. These functions are connected and the altered regions are main, particularly for the maintenance perception of tinnitus[37]. Several studies on tinnitus-related conditions in oto-neurology have been conducted in recent years 38. Causes of tinnitus were not yet found and

these studies are still ongoing[38]. Because the problem occurred in the auditory system, the sound perception was increased for an unknown reason[6,39].

In the current study cervical vestibular evoked myogenic potential (cVEMP) and ocular Vestibular Evoked Myogenic Potential (oVEMP) tests were carried out and data was collected from both the group individuals with the tinnitus (experimental group) and without tinnitus (control group) followed by audiological test battery. The responses of cervical Vestibular Evoked Myogenic Potential (cVEMP) and ocular Vestibular Evoked Myogenic Potential (oVEMP) was compared between the tinnitus and control group and within the tinnitus group (Right *Vs* Left ear & Unilateral (Rt+Lt) *Vs* Bilateral). Results revealed that no statistically significant difference was observed between the control group (individuals with normal hearing) and tinnitus group (individuals who have normal hearing with tinnitus) except bilateral n23 latency and no statistically significant difference were observed within the tinnitus group (Right *Vs* Left ear & Unilateral (Rt+Lt) *Vs* Bilateral) in the measures of cVEMP. However, no statistically significant difference was observed between the control group (individuals with normal hearing) and tinnitus group (individuals who have normal hearing with tinnitus) except left ear p15 latency, left ear peak-to-peak amplitude, bilateral peak-to-peak amplitude in the measures of oVEMP and within the tinnitus group statistically significant difference was observed in the peak-to-peak amplitude of right *Vs* left ear in the oVEMP. The present study results are agreed with the earlier literature. The reason for the significant results with several parameters and no significant results with other parameters in cVEMP and oVEMP recording might be Presymptomatic tinnitus is regarded to occur in ears with normal hearing and abnormal VEMP, while asymptomatic tinnitus may occur in ears with normal VEMP[40-42]. VEMP is sensitive to structural changes in the saccule that are indicative of asymptomatic or pre-symptomatic endolymphatic hydrops, which may be a sign of bilateral MD that is progressing[41,42]. These findings might help to explain why the vestibular system is more resilient than the cochlea, which is impacted more quickly[42-45]. Tinnitus may be the first signs of secondary or delayed endolymphatic hydrops. If this is demonstrated to be accurate, we should anticipate that such patients will gradually develop other endolymphatic hydrops symptoms like SNHL and clinical vestibular dysfunction[46-49].

CONCLUSION

It is important to thoroughly assess all tinnitus patients' auditory and vestibular functions, regardless of whether they exhibit any vestibular symptoms. Doing so will aid in future treatment and prevention.

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REFERENCES

1. Tyler RS, Baker LJ. Difficulties experienced by tinnitus sufferers. J Speech and Hear Dis. 1983;48(2):150-4.
2. Thirunavukkarasu K, Geetha C. One-year prevalence and risk factors of tinnitus in older individuals with otological problems. The Int Tinnitus J. 2013;18(2):175-81.
3. Modh D, Katarkar A, Alam N, Jain A, Shah P. Relation of distortion product otoacoustic emission and tinnitus in normal hearing patients: a pilot study. Noise and Health. 2014;16(69):69.
4. Nemati S, Habibi AF, Panahi R, Pastadast M. Cochlear and brainstem audiologic findings in normal hearing tinnitus subjects in comparison with non-tinnitus control group. Acta Medica Iranica. 2014:822-6.
5. Baguley D, McFerran D, Hall D. Tinnitus. The Lancet. 2013;382(9904):1600-7.
6. Meyerhoff WL, Cooper JC. Tinnitus. Otolaryngol. 1991;2:1169-79.
7. Sharma A, Munjal S, Naresh P, Mohanty M. Demographic Variations in Tinnitus Subjects with and without Hearing Loss: A Study of 175 Subjects. The Int Tinnitus J. 2018; 22(1):77-83.
8. Eggermont JJ. Tinnitus: Neurobiological substrates. Drug discovery today. 2005;10(19):1283-90.
9. Dos Santos RM, Sanchez TG, Bento RF, de Lucia MC. Auditory hallucinations in tinnitus patients: Emotional relationships and depression. IntArch of Otorhinolaryngol. 2012;16(03):322-7.
10. Laird EC, Bryant CA, Barr CM, Bennett RJ. Conversations about mental illness and health in adult audiological rehabilitation. Int J Audiol. 2022:1-8.
11. Bauer CA. Mechanisms of tinnitus generation. Current Opinion in Otolaryngol & Head and Neck Surg. 2004;12(5):413-7.
12. Martines F, Bentivegna D, Martines E, Sciacca V, Martinciglio G. Assessing audiological, pathophysiological and psychological variables in tinnitus patients with or without hearing loss. Eur Arch of Oto-Rhino-Laryngol. 2010;267(11):1685-93.
13. Schlee W, Kleinjung T, Hiller W, Goebel G, Kolassa IT, Langguth B. Does tinnitus distress depend on age of onset?. PloS One. 2011;6(11):e27379.
14. Snow JB. A little goes a long way in tinnitus research. Arch of Otolaryngol–Head & Neck Surg. 2004;130(11):1257-8.
15. Baier B, Dieterich M. Vestibular-evoked myogenic potentials in "vestibular migraine" and Meniere's disease: A sign of an electrophysiological link?. Ann of the New York Acad of Sci. 2009;1164(1):324-7.
16. Murofushi T, Matsuzaki M, Mizuno M. Vestibular evoked myogenic potentials in patients with acoustic neuromas. Arch of Otolaryngol–Head & Neck Surg. 1998;124(5):509-12.
17. Akyıldız N. Tinnitus, Ear diseases and microsurgery II. Sci Med Pub House. 2002:67-81.
18. Dobie RA. Depression and tinnitus. Otolaryngol Clin of North Am. 2003;36(2):383-8.

19. Jastreboff PJ. Phantom auditory perception (tinnitus): Mechanisms of generation and perception. Neurosci Research. 1990;8(4):221-54.

20. Kaltenbach JA. Neurophysiologic mechanisms of tinnitus. J Am Acad of Audiol. 2000;11(03):125-37.

21. Admis A, Unsal S, Gunduz M. Evaluation of vestibular evoked Myogenic potentials (VEMP) individuals with tinnitus and normal hearing. The Int Tinnitus J. 2019;23(1):58-63.

22. House JW. Tinnitus: evaluation and treatment. Otol & Neurotol. 1984;5(6):472-5.

23. Morales-Garcia C, Quiroz G, Matamala JM, Tapia C. Neuro-otological findings in tinnitus patients with normal hearing. The J Laryngol & Otol. 2010;124(5):474-6.

24. Kadan İ, Kirazlı G, Öğüt MF, Kirazlı T. Evaluation of Vestibulo-Ocular Reflex (VOR) in Tinnitus Patients with Normal Hearing. The J Int Adv Otol. 2021;17(1):13.

25. Weshahy DH, Salama M, Mohamed ES. Vestibular evaluation of patients with unilateral subjective idiopathic tinnitus. Egy J Neck Surg and Otorhinolaryngol. 2019;5(1):35-44.

26. Borton TE, Moore Jr WH, Clark SR. Electromyographic feedback treatment for tinnitus aurium. J Speech and Hear Dis. 1981;46(1):39-45.

27. Rosengren SM, Welgampola MS, Colebatch JG. Vestibular evoked myogenic potentials: past, present and future. Clin Neurophysiol. 2010;121(5):636-51.

28. Sinha SK, Barman A, Singh NK, Rajeshwari G, Sharanya R. Involvement of peripheral vestibular nerve in individuals with auditory neuropathy. European Arch of Oto-Rhino-Laryngol. 2013;270(8):2207-14.

29. Wang H, Brozoski TJ, Turner JG, Ling L, Parrish JL, Hughes LF, et al. Plasticity at glycinergic synapses in dorsal cochlear nucleus of rats with behavioral evidence of tinnitus. Neurosci. 2009;164(2):747-59.

30. Govender S, Rosengren SM, Colebatch JG. The effect of gaze direction on the ocular vestibular evoked myogenic potential produced by air-conducted sound. Clin Neurophysiol. 2009;120(7):1386-91.

31. Akin FW, Murnane OD. Head injury and blast exposure: vestibular consequences. Otolaryngologic Clin of North Am. 2011;44(2):323-34.

32. Rosengren SM, Colebatch JG, Straumann D, Weber KP. Why do oVEMPs become larger when you look up? Explaining the effect of gaze elevation on the ocular vestibular evoked myogenic potential. Clin Neurophysiol. 2013;124(4):785-91.

33. Singh NK, Kashyap RS, Supreetha L, Sahana V. Characterization of age-related changes in sacculocolic response parameters assessed by cervical vestibular evoked myogenic potentials. Eur Arch of Oto-Rhino-Laryngol. 2014;271(7):1869-77.

34. Murofushi T, Kaga K. Meniere's Disease and Related Disorders: Detection of Saccular Endolymphatic Hydrops. Vest Evoked Myogenic Pot: Its Bas and Clin App. 2009:49-59.

35. Colebatch JG, Halmagyi GM. Vestibular evoked potentials in human neck muscles before and after unilateral vestibular deafferentation. Neurol. 1992;42(8):1635.

36. Chihara Y, Iwasaki S, Ushio M, Murofushi T. Vestibular-evoked extraocular potentials by air-conducted sound: another clinical test for vestibular function. Clin Neurophysiol. 2007;118(12):2745-51.

37. Elgoyhen AB, Langguth B, De Ridder D, Vanneste S. Tinnitus: perspectives from human neuroimaging. Nature Rev Neurosci. 2015;16(10):632-42.

38. Akkuzu G, Akkuzu B, Ozluoglu LN. Vestibular evoked myogenic potentials in benign paroxysmal positional vertigo and Meniere's disease. Eur Arch of Oto-Rhino-Laryngol and Head & Neck. 2006;263(6):510-7.

39. Davis A, Refaie A, Tyler R. Tinnitus handbook. USA: Thompson Learning. 2000; 1(6).

40. Toptas G, Keseroglu K, Saka C, Er S, Korkmaz MH. Is There Any Effect of Subjective Tinnitus on Vestibular Evoked Myogenic Potentials. The Int Tinn J. 2020;24(2):54-9.

41. Vitkovic J, Paine M, Rance G. Neuro-otological findings in patients with migraine-and nonmigraine-related dizziness. Audiol and Neurotol. 2008;13(2):113-22.

42. Mohamed ES, Ahmed MA, Said EA. Role of cervical vestibular-evoked myogenic potentials testing in vestibular migraine. Egy J of Ear, Nose, Throat and Allied Sci. 2015;16(2):139-44.

43. Neuhauser H, Lempert T. Vertigo and dizziness related to migraine: a diagnostic challenge. Cephalalgia. 2004;24(2):83-91.

44. Baier B, Stieber N, Dieterich M. Vestibular-evoked myogenic potentials in vestibular migraine. J Neurol. 2009;256(9):1447-54.

45. Allena M, Magis D, Pasqua VD, Schoenen J. The vestibulo-collic reflex is abnormal in migraine. Cephalalgia. 2007;27(10):1150-5.

46. Murofushi T, Matsuzaki M, Takegoshi H. Glycerol affects vestibular evoked myogenic potentials in Meniere's disease. Auris Nasus Larynx. 2001;28(3):205-8.

47. Shulman A. Secondary endolymphatic hydrops—tinnitus. Otolaryngol—Head and Neck Surg. 1991;104(1):146-7.

48. De Waele CA, Tran Ba Huy P, Diard JP, Freyss G, Vidal PP. Saccular dysfunction in Menière's patients: A vestibular-evoked myogenic potential study. Ann of the New York Acad of Sci. 1999;871(1):392-7.

49. Fouly H, Minawi ME, Dessouki TE. Value of VEMP in detecting saccular affection in the asymptomatic ear in the patients with meniere's disease. Medical J Cario Univ. 2012;80(1):397-403.