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Cervical and ocular vestibular-evoked myogenic potentials test results and its relation to vestibular signs and symptoms in individuals with vestibular migraine

Adithya Sreedharan Sanitha^{1*}  and Sujeet Kumar Sinha¹

Abstract

Objective The objective of the present study was to characterize the response rate, latency, and amplitude parameters of the cervical and ocular vestibular evoked myogenic potentials in individuals with vestibular migraine. The objective was also to describe the signs and symptoms exhibited by individuals with vestibular migraine and find out an association with VEMP results.

Method Thirty individuals with a diagnosis of vestibular migraine and thirty healthy individuals participated in the study. The diagnosis of the vestibular migraine was made based on the diagnosis criteria given by the Barany Society and the International Headache Society. Cervical and ocular vestibular evoked myogenic potentials were recorded using 500 Hz tone burst stimulus for all the participants in both groups.

Results The latency was prolonged, and the amplitude was reduced for both the cervical and ocular vestibular evoked myogenic potentials in individuals with vestibular migraine compared with healthy individuals. There was no association between signs and symptoms exhibited by vestibular migraine individuals and VEMP results.

Conclusions Both the sacculocollic and otolith ocular pathways are affected in vestibular migraine. Hence, there is a necessity for vestibular evaluation in all patients with vestibular migraine to understand the spectrum of the pathology.

Keywords Vestibular evoked myogenic potentials, Cervical vestibular evoked myogenic potentials, Ocular vestibular evoked myogenic potentials, Migraine, Vestibular migraine

Background

Vestibular migraine is one of the most common causes of episodic vertigo. Vestibular migraine has gained recognition as a distinct clinical entity in recent years. Vestibular migraine is the second most common cause of dizziness in vertigo clinics after benign paroxysmal positional

vertigo [1, 2]. The prevalence of vestibular migraine in vertigo clinics has been estimated to be around 7 to 16% [1, 2]. In a German study, Neuhauser et al. [3] reported the prevalence of vestibular migraine to be 0.89% and 0.98% of the adult general population.

There are equivocal findings of cervical VEMP in individuals with vestibular migraine. Some reports suggest increased latency for cVEMP in vestibular migraine patients compared with normal healthy individuals [4, 5]. The delayed latency could be due to the central vestibular lesions in individuals with vestibular migraine. At the same time, many studies have reported no significant

*Correspondence:

Adithya Sreedharan Sanitha
adithyass67@gmail.com

¹ Department of Audiology, All India Institute of Speech and Hearing, Mysore, India

delay in latency of p13 or n23 in individuals with vestibular migraine [6, 7].

Even there are equivocal findings regarding the amplitude of cVEMP in individuals with vestibular migraine. Some reports suggest a reduced p13-n23 amplitude in individuals with vestibular migraine [4]. At the same time, other studies have reported no significant difference in p13-n23 amplitude between vestibular migraine and healthy individuals [6]. The discrepancy in the results between the studies could be due to the methodological shortcomings. In most of these studies groups tested were generally small, and the cVEMP p13-n23 amplitude was neither standardized nor EMG corrected.

Several studies have reported reduced amplitude and delayed latency of ocular VEMP in individuals with vestibular migraine [4, 7]. At the same time, few studies have reported no significant difference in latency or amplitude parameters in vestibular migraine compared with normals [5, 6]. The differences in findings could be due to patient selection criteria, the difference in diagnostic criteria used for vestibular migraine, other stimuli, and recording parameters used for the recording of VEMP. Also, the findings of oVEMP are limited in individuals with vestibular migraine. Combining oVEMP and cVEMP will provide information regarding the saccollic and otolith ocular pathway in vestibular migraine patients.

The vestibular signs and symptoms of vestibular migraine are vertigo (lasting 5 min to 72 h), nausea or vomiting, falling, swaying or imbalance, blackouts, and blurring of vision [8]. The triggering factors for vestibular symptoms are stress, motion sickness, lack of sleep, lack of food, changes in head position, gazing, phonophobia, and photophobia. The symptoms are more in individuals having chronic migraine or long-standing migraine problems. The signs and symptoms reported across the different studies are different. The differences in signs and symptoms reported across the study could be because of the patient population studied across various studies. None of the studies have correlated the VEMP test results with the signs and symptoms the vestibular migraine patients exhibited. Hence, we have made an attempt of correlating the VEMPs findings with the signs and symptoms exhibited by the vestibular migraine patients.

Methods

Participants

Sixty subjects aged 18–50 years were selected for the study (56 females and 4 males). Participants were divided into two groups. Group 1 consisted of 30 healthy individuals with no vestibular migraine or any other audio-vestibular disorders. Group 2 consisted of thirty individuals with vestibular migraine. Vestibular migraine

was diagnosed according to the Consensus document of the Barany Society and the International Headache Society [9]. A neurologist confirmed the diagnosis of migraine for vestibular migraine patients. Participants of both groups had no otological complaints. All the participants in both groups had normal hearing in both ears (<15 dBHL). Tympanometry test revealed an absence of middle ear pathology for both groups of participants (A/As type of tympanogram with presence of acoustic reflexes). Individuals who participated in the study did not have diabetes or hypertension. An informed consent was taken from all the participants prior to the testing.

Procedure

A detailed case history was taken initially from all the participants. For all the participants in both groups, routine audiological evaluations, pure tone audiometry, and tympanometry were done.

Vestibular evoked myogenic potentials

Air conduction cervical and ocular VEMP were recorded using Neurosoft's NeuroAudio instrument. Stimuli were presented through ER-3A insert earphones. The tests were randomized, and subjects were given a rest period of 2 min between the recordings.

Cervical VEMP

cVEMP recordings were done ipsilaterally. The active electrode was placed at the upper 1/3rd of the sternocleidomastoid (SCM) muscle; the reference electrode was at the sternoclavicular joint, and the ground electrode was placed at the forehead. The head was turned towards the side opposite to the stimulated ear to produce tonic contraction of the SCM during recording. The computer display provided visual feedback for the patients to maintain the required muscle contraction. cVEMP were recorded using 500 Hz tone burst stimulus (2–0–2) with an intensity level of 125 dB SPL. The repetition rate was kept at 5.1/s, and the stimulus was presented in an alternating polarity. cVEMP responses were band pass filtered between 10 and 1500 and averaged 200 times with an amplification factor of 5000. The analysis window of cVEMP was kept at 74 ms, including a prestimulus time of ten msec.

Ocular VEMP

oVEMP recordings were done contralaterally. The active electrode was placed 1 cm below the lower eyelid, the reference electrode was 1 cm below the active electrode, and the ground electrode was placed at the forehead. The patients were instructed to maintain a neutral head position with a constant upward gaze of 30°. oVEMP were recorded using 500 Hz tone burst stimulus (2–0–2) with

an intensity level of 125 dB SPL. The repetition rate was kept at 5.1/s, and the stimulus was presented in an alternating polarity. oVEMP responses were band pass filtered between 0.1 and 1000 and averaged 200 times with an amplification factor of 30,000 times. The analysis window of oVEMP was kept at 74 ms, including a prestimulus time of 10 ms.

Data analysis

For cVEMP testing, latency of p13 and latency of n23, EMG-rectified amplitude of p13-n23 complex, and amplitude asymmetry ratio were considered for analysis. Similarly, the latency of n10, p15, amplitude of n10-p15 complex, and asymmetry ratio were used to analyze oVEMP. The median and the interquartile range of the latency and amplitude parameters of cVEMP and oVEMP were calculated. The normality of the data was analyzed using Shapiro–Wilk's test. Wilcoxon signed rank test was used to analyze significant differences in latency and the amplitude parameters of cVEMP and oVEMP between the two ears. The Mann–Whitney *U* test was performed to compare the data between healthy individuals and individuals with vestibular migraine. The correlation between the cervical VEMP and ocular VEMP findings was analyzed using Spearman's correlation test. The association between the vestibular signs, associated symptoms, and vestibular test results were analyzed using a chi-square test. The individual data was first categorized into normal and abnormal VEMPs results. For classifying the data into the normal and abnormal VEMPs results, 95% confidence interval of median was calculated. The upper limit value was calculated using the formula $nq + z \sqrt{nq(1 - q)}$ and lower limit using the formula $nq - z \sqrt{nq(1 - q)}$ [10]. If the latency value of

cVEMP and oVEMP of vestibular migraine patients was higher than the upper limit value of healthy individuals, it was considered abnormal. If the amplitude of cVEMP and oVEMP of vestibular migraine patients was less than lower limit value of healthy individuals, it was considered abnormal.

Results

Out of 30 individuals diagnosed with vestibular migraine, 28 were females, and 2 were males. The mean age group for group 1 individuals were 28.35 ± 7.16 years, and for group 2 was 31.03 ± 8.21 years.

The response rate of vestibular evoked myogenic potentials in vestibular migraine

Cervical VEMP and ocular VEMP responses were present in all the healthy individuals. Cervical VEMP responses were absent in four individuals bilaterally and three unilaterally in the vestibular migraine population. Ocular VEMP was absent in six individuals bilaterally and nine unilaterally in the vestibular migraine population.

Cervical VEMP test results

Table 1 shows the median and interquartile range of latency and amplitude parameters for healthy individuals and individuals with vestibular migraine.

Wilcoxon signed rank test showed no significant difference in p13 latency ($Z=0.15$, $p=0.87$), n23 latency ($Z=0.14$, $p=0.88$), and p13-n23 rectified amplitude ($Z=0.31$, $p=0.75$) for cVEMP between the two ears for healthy individuals. For individuals with vestibular migraine, the Wilcoxon signed rank test showed no significant difference in p13 latency ($Z=0.12$, $p=0.19$), n23

Table 1 Median and interquartile range for latency and amplitude parameters of right and left ear separately for healthy individuals and individuals with vestibular migraine

| Groups | Ear | Parameter | N | Median | IQR |
|---------------------------------|-------|---------------------|----|--------|-------------|
| Healthy individuals | Right | P13 latency | 30 | 12.15 | 11.80–12.65 |
| | | N23 latency | 30 | 20.15 | 19.75–20.80 |
| | | Rectified amplitude | 30 | 1.95 | 1.60–2.60 |
| | Left | P13 latency | 30 | 12.40 | 11.75–12.62 |
| | | N23 latency | 30 | 20.20 | 19.80–21.12 |
| | | Rectified amplitude | 30 | 1.95 | 1.47–2.70 |
| Vestibular migraine individuals | Right | P13 latency | 25 | 13.40 | 12.70–14.35 |
| | | N23 latency | 25 | 21.00 | 20.15–22.20 |
| | | Rectified amplitude | 25 | 1.50 | 1.05–1.80 |
| | Left | P13 latency | 24 | 13.80 | 13.00–14.15 |
| | | N23 latency | 24 | 21.60 | 20.20–22.27 |
| | | Rectified amplitude | 24 | 1.40 | 0.80–1.80 |

IQR Interquartile range

latency ($Z=0.33$, $p=0.74$), and p13-n23 rectified amplitude ($Z=0.82$, $p=0.41$) for cVEMP between the two ears. Hence, the data from both the ears were combined for both the groups. Further statistics were done for the combined data of the two ears.

Figure 1 shows the individual and grand averaged cVEMP waveform for healthy and vestibular migraine individuals for the combined data.

Figure 2 shows the median, lower, and upper quartile values for the combined cVEMP data for healthy vestibular migraine individuals.

Mann–Whitney U test revealed a significant difference between the two groups for cVEMP p13 latency ($Z=6.9$, $p=0.00$), n23 latency ($Z=3.5$, $p=0.00$), rectified amplitude ($Z=4.9$, $p=0.00$), and amplitude asymmetry ratio ($Z=3.3$, $p=0.00$). To summarize the results, the latency of cVEMP was prolonged, and amplitude was reduced for vestibular migraine individuals compared with healthy individuals. Also, the amplitude asymmetry ratio was higher for vestibular migraine patients than for healthy individuals.

Ocular VEMP test results

Table 2 shows the median and interquartile range for latency and amplitude parameters for healthy individuals and individuals with vestibular migraine.

Wilcoxon signed rank test showed no significant difference in n10 latency ($Z=0.41$, $p=0.96$), p15 latency ($Z=0.95$, $p=0.34$), and rectified amplitude for oVEMP ($Z=1.41$, $p=0.25$) between the two ears for healthy

individuals. For vestibular migraine individuals, the Wilcoxon signed rank test showed no significant difference in n10 latency ($Z=0.28$, $p=0.77$), p15 latency ($Z=0.54$, $p=0.58$), and rectified amplitude for oVEMP ($Z=0.54$, $p=0.58$) between the two ears. Hence, the data from both ears were combined for both groups separately.

Figure 3 shows individuals and grand averaged oVEMP waveforms for healthy and vestibular migraine individuals.

Figure 4 shows the median, lower, and upper quartile values for the combined data for healthy vestibular migraine individuals.

Mann Whitney U test revealed a significant difference between the two groups for n10 latency ($Z=5.48$, $p=0.00$), p15 latency ($Z=5.06$, $p=0.00$), rectified amplitude ($Z=4.50$, $p=0.00$), and asymmetry ratio ($Z=4.1$, $p=0.00$) between the two groups. Overall, the oVEMP latency was prolonged, the amplitude was reduced, and the amplitude asymmetry ratio was higher in vestibular migraine than in healthy individuals.

Correlation between cVEMP and oVEMP parameters

Spearman's correlation test revealed no significant correlation ($r=0.17$, $p=0.34$) between p13 and n10 peak latency, between n23 and p15 peak latency ($r=0.08$, $p=0.65$), and between p13-n23 amplitude and n10-p15 amplitude ($r=0.31$, $p=0.08$) in vestibular migraine individuals.

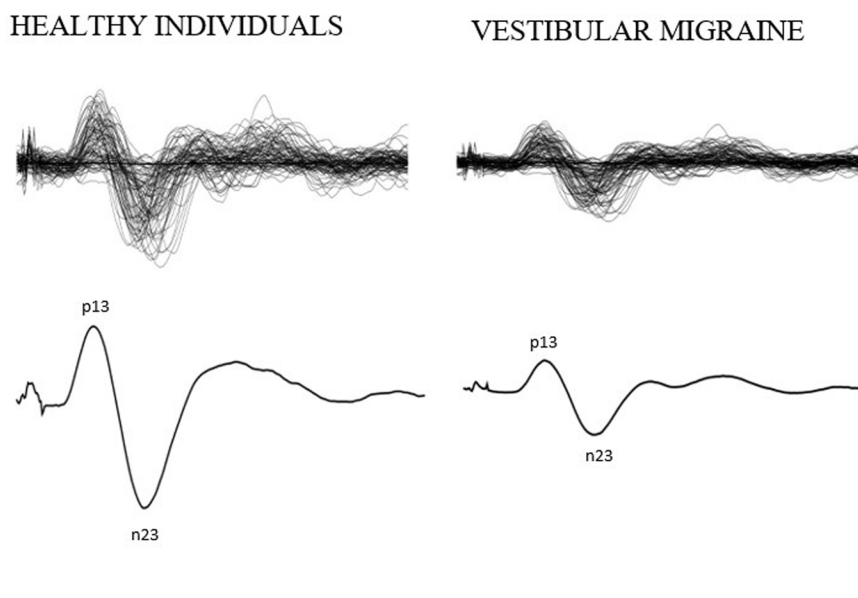


Fig. 1 Individual and grand averaged cVEMP waveforms for healthy and vestibular migraine participants

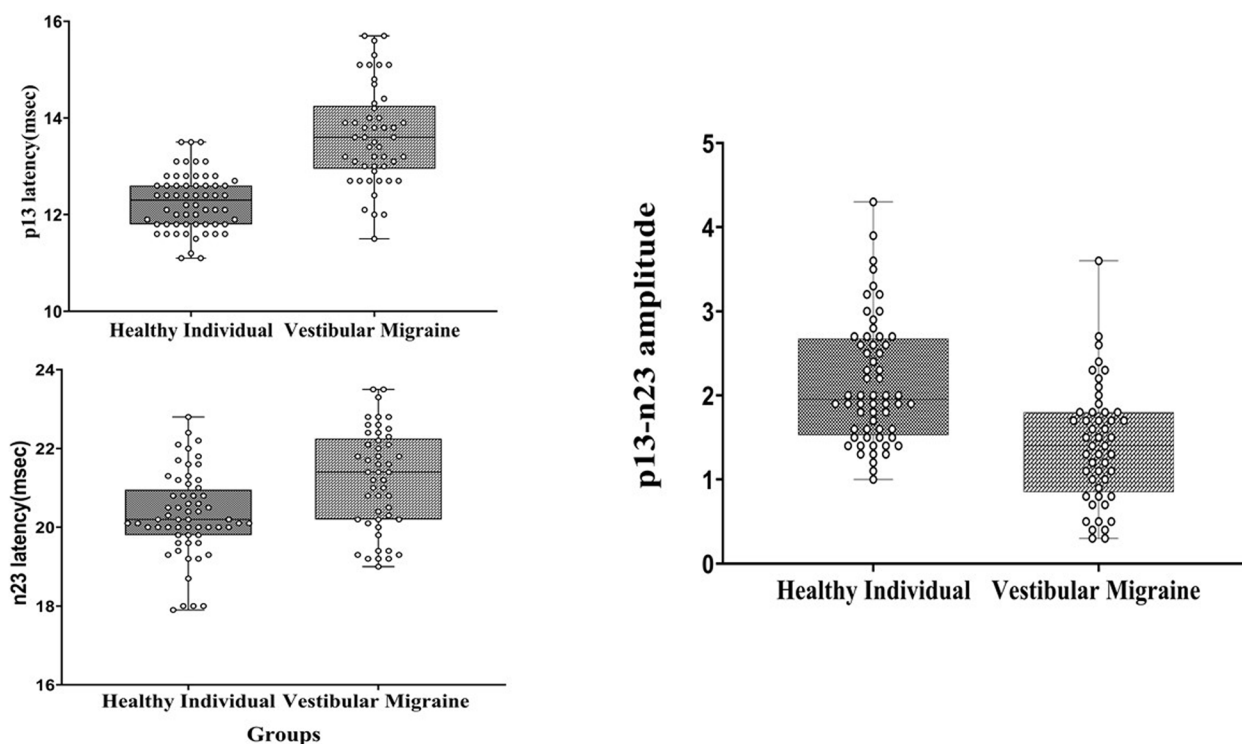


Fig. 2 Box plot showing the cVEMP latency and amplitude parameters for the combined data

Table 2 Median and interquartile range for latency and amplitude parameters of oVEMP in healthy individuals and individuals migraine for left and right ear separately

| Groups | Ear | Parameter | N | Median | IQR |
|---------------------------------|-------|---------------------|----|--------|-------------|
| Healthy individuals | Right | N10 latency | 30 | 9.70 | 8.97–10.22 |
| | | P15 latency | 30 | 14.70 | 14.02–15.27 |
| | | Rectified amplitude | 30 | 1.35 | 0.70–1.92 |
| | Left | N10 latency | 30 | 9.70 | 9.10–10.22 |
| | | P15 latency | 30 | 14.80 | 14.20–15.65 |
| | | Rectified amplitude | 30 | 1.10 | 0.87–2.10 |
| Vestibular migraine individuals | Right | N10 latency | 23 | 10.80 | 10.10–10.90 |
| | | P15 latency | 23 | 16.0 | 15.20–16.20 |
| | | Rectified amplitude | 23 | 0.70 | 0.30–1.00 |
| | Left | N10 latency | 16 | 10.70 | 9.92–11.00 |
| | | P15 latency | 16 | 16.30 | 15.12–17.47 |
| | | Rectified amplitude | 16 | 0.60 | 0.30–0.77 |

IQR Interquartile range

Association between the signs and symptoms in vestibular migraine individuals and vestibular test results

The demographic details and the signs and symptoms seen in individuals with vestibular migraine are shown in Table 3.

As per the 95% confidence interval of median, delayed cVEMP latency was found in 16 patients, and reduced amplitude of cVEMP was found in 15 patients

with vestibular migraine. Delayed oVEMP latency was found to be in 11 patients and reduced oVEMP amplitude was found in 13 patients with vestibular migraine. The Chi-square test did not show any significant association between the signs and symptoms exhibited by the vestibular migraine patients and the cVEMP and oVEMP latency and amplitude parameters ($p > 0.05$). Chi-square also did not show any significant

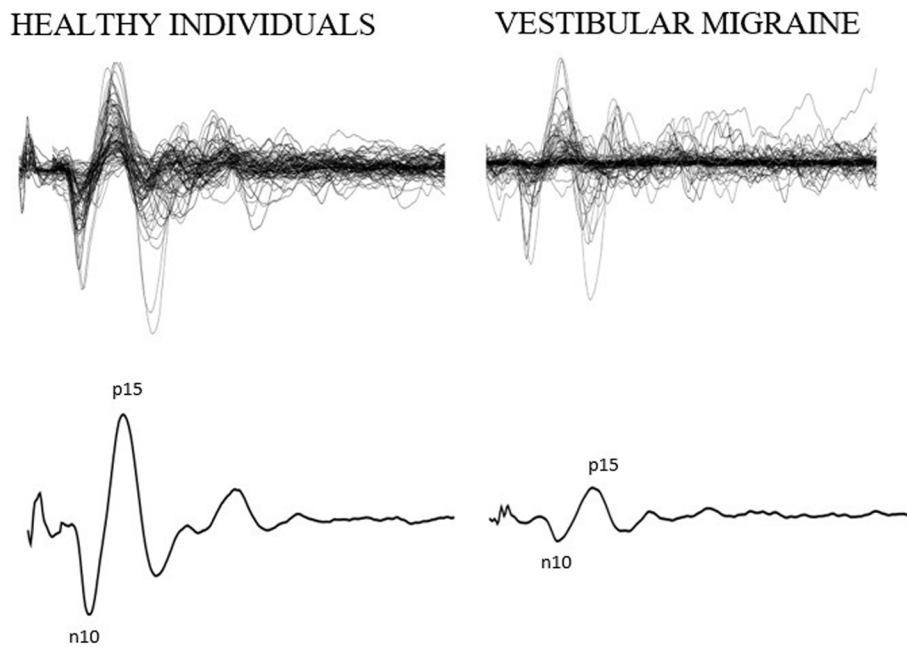


Fig. 3 Individual and grand averaged oVEMP waveforms for healthy and vestibular migraine participants

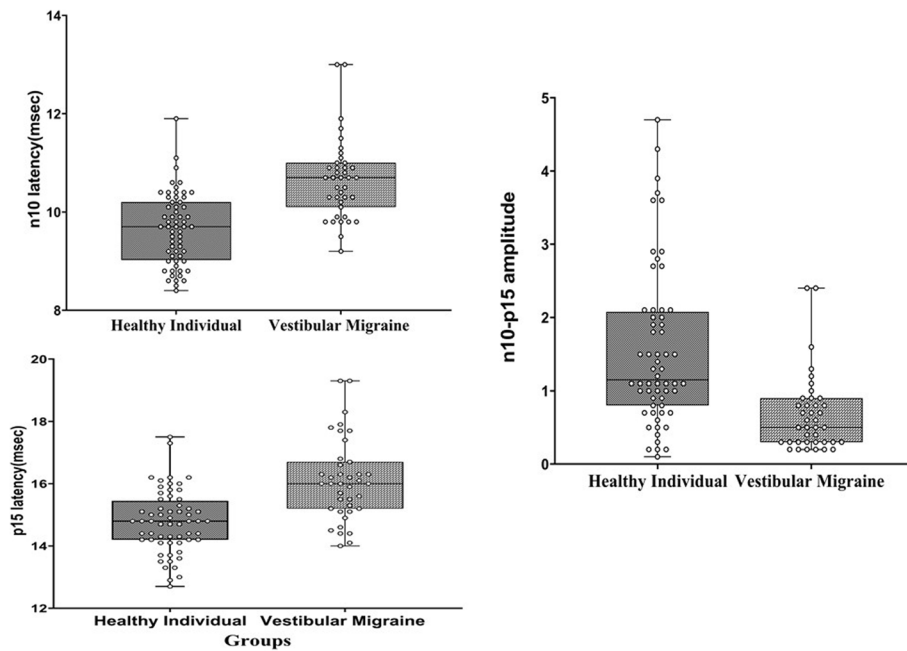


Fig. 4 Boxplot showing the oVEMP latency and amplitude parameters for healthy and vestibular migraine individuals

association between the duration of the problem and the cVEMP and oVEMP latency and amplitude parameters ($p > 0.05$). The results of Chi-square test is given in Table 4.

Discussion

The present study evaluated cervical and ocular VEMP in individuals with vestibular migraine. Also, the present study assessed the association between vestibular

Table 3 The demographic details and the sign and symptoms exhibited by individuals with vestibular migraine

| Sl. No | Age (years)/gender | Vestibular symptoms | Duration of the problem | Motion sickness | Lack of sleep | Phonophobia | Photophobia | Positional vertigo | Gaze induced vertigo |
|--------|--------------------|---|-------------------------|-----------------|---------------|-------------|-------------|--------------------|----------------------|
| 1. | 32/F | Spinning, falling, blurring of vision | 1 year | A | P | P | P | P | P |
| 2. | 25/F | Spinning, blurring of vision, imbalance | 3 months | P | P | P | P | P | A |
| 3. | 35/F | Spinning, swaying, falling | 1 year | A | A | P | P | A | A |
| 4. | 30/F | Spinning, falling, dizziness | 5 months | P | A | A | P | P | P |
| 5. | 18/F | Spinning, falling, light headedness | 4 weeks | A | P | P | P | P | P |
| 6. | 30/M | Spinning, imbalance, falling | 1 month | A | P | P | P | P | P |
| 7. | 22/F | Spinning, falling, blurring of vision | 1 year | A | A | P | P | P | A |
| 8. | 22/F | Spinning, imbalance, dizziness | 5 years | A | P | P | A | A | P |
| 9. | 37/F | Spinning, falling, imbalance | 1 year | A | P | P | P | P | A |
| 10. | 43/F | Spinning, dizziness, blurring of vision | 1 year | A | P | P | P | A | A |
| 11. | 39/F | Spinning, dizziness | 1 week | P | P | P | P | P | P |
| 12. | 38/F | Spinning, imbalance, falling | 5 years | A | P | A | A | P | A |
| 13. | 41/F | Spinning, blurring of vision | 1 month | A | A | P | A | A | A |
| 14. | 23/F | Spinning, imbalance, blurring of vision | 3 years | A | A | P | P | P | A |
| 15. | 30/F | Spinning, falling, blurring of vision | 1 year | A | P | P | P | A | A |
| 16. | 28/F | Spinning, falling, dizziness | 1 week | A | P | P | P | P | A |
| 17. | 30/F | Spinning, imbalance, falling | 1 month | A | P | P | P | P | P |
| 18. | 18/F | Spinning, falling, blurring of vision | 2 months | P | A | P | A | P | A |
| 19. | 20/F | Spinning, falling, blurring of vision | 5 years | A | P | P | P | P | P |
| 20. | 45/F | Spinning, falling, dizziness | 1 year | A | P | P | P | P | P |
| 21. | 23/F | Spinning, falling, blurring of vision | 5 years | A | P | P | A | P | P |
| 22. | 38/M | Spinning, falling, imbalance | 5 months | A | A | P | P | P | A |
| 23. | 43/F | Spinning, imbalance, blurring of vision | 1 year | P | A | P | P | A | A |
| 24. | 27/F | Spinning, imbalance, blurring of vision | 4 days | A | P | P | P | P | A |
| 25. | 32/F | Spinning, blurring of vision, falling | 2 months | A | P | P | P | P | P |
| 26. | 22/F | Spinning, imbalance, falling | 15 days | P | P | P | P | A | A |
| 27. | 32/F | Spinning, imbalance, dizziness | 1 year | P | A | A | A | A | A |
| 28. | 29/F | Spinning, falling, blurring of vision | 3–4 years | P | P | P | P | P | P |
| 29. | 32//F | Spinning, falling, dizziness | 1 week | A | P | P | P | A | A |
| 30. | 47//F | Spinning, falling, dizziness | 6 months | A | P | P | P | P | A |

A Absent, P Present

Table 4 Association between vestibular symptoms, duration of the vestibular symptoms with cVEMP and oVEMP parameters

| | Test | Test parameter | χ^2 | <i>p</i> |
|-------------------------|-------|-----------------------|----------|----------|
| Vestibular symptoms | cVEMP | p13 latency | 5.48 | 0.70 |
| | | n23 latency | 1.96 | 0.74 |
| | | p13-n23 amplitude | 1.96 | 0.74 |
| | | cVEMP asymmetry ratio | 2.84 | 0.58 |
| | oVEMP | n10 latency | 0.91 | 0.92 |
| | | p15 latency | 0.91 | 0.92 |
| | | n10-p15 amplitude | 5.87 | 0.66 |
| | | oVEMP asymmetry ratio | 1.98 | 0.73 |
| Duration of the problem | cVEMP | p13 latency | 9.03 | 0.70 |
| | | n23 latency | 8.22 | 0.22 |
| | | p13-n23 amplitude | 8.22 | 0.22 |
| | | cVEMP asymmetry ratio | 8.82 | 0.18 |
| | oVEMP | n10 latency | 6.58 | 0.36 |
| | | p15 latency | 6.58 | 0.36 |
| | | n10-p15 amplitude | 10.78 | 0.54 |
| | | oVEMP asymmetry ratio | 7.05 | 0.31 |

migraine patient's vestibular signs and symptoms and the duration of the vestibular signs and symptoms with the cervical and ocular VEMPs. Among the individuals selected for the study, 93% (28/30) were female. The higher incidence in female individuals is due to various genetic and epigenetic factors.

Response rate

The results of the present study revealed an absence of cervical VEMP in 5% unilaterally and 7% of the patients with vestibular migraine bilaterally. The ocular VEMP was absent in 15% of the vestibular migraine unilaterally and 10% of the vestibular migraine bilaterally. The present study showed more absent responses for ocular VEMP testing than cervical VEMP in patients with vestibular migraine.

The absence of cVEMP and oVEMP ranges between 5 and 95% in patients with vestibular migraine [4, 5, 11]. The absence of cervical and ocular VEMP in patients with vestibular migraine could be due to vestibular dysfunction. The vestibular dysfunction in vestibular migraine patients could arise due to the vasospasm of the labyrinthine artery [12]. The vasospasm of the labyrinthine artery could be affecting the saccule and the utricle more due to the mean capillary diameter for the saccule and utricle. The mean capillary diameter of the otoliths is about 4.6 μm , whereas most other body capillaries are larger, averaging 7–9 μm in diameter [13]. Due to the smaller diameter of the capillaries, the vasospasm will reduce the blood flow more to the otoliths than the other organs; hence, the chances of absence/abnormal

vestibular evoked myogenic potentials could be higher in patients with vestibular migraine. Such vasospasm of the labyrinthine artery in individuals with migraine could be a secondary phenomenon due to the presence of some metabolic disorders [13]. The vasospasm of the inner ear might take place after a primary metabolic disorder of the inner ear [12].

Fujimoto et al. [14] reported that individuals with definite vestibular migraines have more abnormal utriculo-ocular reflex pathway dysfunction than cervical VEMP. Zaleski et al. [15] reported higher rates of abnormal oVEMPs in vestibular migraine patients. Makowiec et al. [16] reported that patients with vestibular migraine may exhibit normal cVEMP responses in the presence of unilaterally abnormal oVEMP responses. The absence of oVEMP more than cVEMP has also been reported in individuals with severe to profound sensorineural hearing loss [17], patients with bilateral vestibulopathy due to aminoglycosides toxicity [18], and BPPV [19]. Thus, the absence of oVEMP more than cVEMP may not be a significant biomarker for the diagnosis of vestibular pathology in patients with vestibular migraine. The absence of oVEMP more than cVEMP could be an indicator that the utricle may be more damaged compared to the saccule in individuals with vestibular migraine.

Latency and amplitude of vestibular evoked myogenic potentials

The results of the present study showed a significant prolongation of cVEMP and oVEMP latency in vestibular migraine patients compared with the healthy control. The same findings have also been reported in various literature.

Many other authors have reported latency delay in cVEMP in vestibular migraine patients [4, 7]. These studies support the hypothesis of the involvement of the central vestibular pathway in individuals with vestibular migraine. Using F-fluorodeoxyglucose (FDG) positron emission tomography, Shin et al. [20] reported that the vestibulothalamo-vestibulocortical pathway is activated during vestibular migraine attacks, as evidenced by increased metabolism in the temporal-parietal-insular regions and bilateral thalami, and decreased metabolism in the occipital cortex, which may signify reciprocal inhibition between the visual and vestibular systems. Lee et al. [21] reported that the vestibular structures in the brainstem and cerebellum appear more susceptible to ischemia than any other areas. So, the vascular changes in migraine patients might affect the central vestibular systems. The damage to the central vestibular pathways in individuals with vestibular migraine may be a reason for the prolongation of the latency of both the cVEMP and oVEMP.

The amplitude of cVEMP and oVEMP was reduced for individuals with vestibular migraine compared to healthy individuals. Several other authors have also reported a significant decrease in the amplitude of the cVEMP and oVEMP in individuals with vestibular migraine compared with healthy individuals [7]. The reduction in amplitude of cVEMP and oVEMP could be due to the damage of the saccule and utricle or their innervating structures in individuals with vestibular migraine. Such vestibular damage in vestibular migraine could occur due to the vasospasm of the labyrinthine artery [12], faulty voltage-gated calcium-channel genes, mutations in other calcium channel [22], and neurogenic inflammation of the trigeminal nerve in vestibular migraine [23].

The results of the present study did not show any significant correlation between the cVEMP and oVEMP findings in patients with vestibular migraine. Various other studies have also reported no correlation between cVEMP and oVEMP in various other vestibular disorders such as Meniere's disease [24], vestibular neuritis [24], severe to profound sensorineural hearing loss [17], and benign paroxysmal positional vertigo [25]. These results are consistent with the idea that the oVEMP in response to acoustic stimulation represents utricular functions, and the cVEMP in response to auditory stimulation primarily reflects saccular functions. Hence, the cVEMP and oVEMP might reflect different functions in various vestibular disorders [24]. Hence, the results of the present study are consistent with the results of the other studies that there is no correlation between cVEMP and oVEMP in vestibular disorders.

As both the latency and amplitude parameters of VEMPs are affected, the results could be indicative of both peripheral as well as central lesion in vestibular migraine patients. Previous reports on vestibular evoked myogenic potentials suggest a delay in the latency of vestibular evoked myogenic potential peaks in various brainstem disorders. However, the latency of the vestibular evoked myogenic potential peak remains within normal limits in individuals with peripheral vestibular disorders [26]. It has also been suggested that the amplitude of the vestibular evoked myogenic potentials depends upon the integrity of the peripheral vestibular functions [26]. The evidence of the same also comes from the studies that reported latency and amplitude in individuals with superior canal dehiscence syndrome and Meniere's disease. In patients with superior canal dehiscence syndrome, the amplitude of VEMP is enhanced in ipsilesional ears [27], whereas the amplitude of the VEMP is either reduced or VEMPs are absent in Meniere's disease patients [28]. The VEMPs are also absent in various other disorders that affect the nervous system, such as auditory neuropathy spectrum disorders [29], brainstem stroke [30], and

multiple sclerosis [31]. Thus, if we consider the findings of the above studies, it may be concluded that vestibular migraine patients can have lesions both in the peripheral and central vestibular systems.

Signs and symptoms of vestibular migraine

Individuals with vestibular migraine were selected based on the criteria developed by the Barany Society and International Classification of Headache Disorders [9]. Individuals with vestibular migraine in the present study showed various vestibular signs and symptoms. The individuals with vestibular migraine reported different characteristics of giddiness such as spinning, falling sensation, swaying/imbalance, blurring of vision, and dizziness. Along with the symptoms mentioned above, vestibular migraine patients also showed symptoms such as intolerance to loud sounds, intolerance to bright light, positional vertigo, gaze-induced vertigo, stress-induced vertigo, and lack of sleep. One or the other symptoms described above were seen in almost all the individuals with vestibular migraine.

Vestibular migraine is a heterogeneous condition with a wide range of symptoms [32]. The spectrum of symptom manifestation for vestibular migraines ranges from episodic to chronic and is similar to that of the migraine itself. The different signs and symptoms exhibited by patients with vestibular migraine across different studies are shown in Table 5.

Table 5 Signs and symptoms exhibited by individuals with vestibular migraine

| Symptoms | Kim et al. [33] | Teggi et al. [34] | Present study |
|--------------------------|-----------------|-------------------|---------------|
| Headache | 79.90% | 100% | 100% |
| Photophobia | 55.40% | - | 76.60% |
| Phonophobia | 40.50% | - | 90% |
| Visual aura | 28.40% | - | - |
| Increased anxiety levels | 48.60% | - | - |
| Depression | 32.40% | - | - |
| Vertigo | 100% | 73.50% | 100% |
| Dizziness | - | 44.10% | 33.30% |
| Nausea | - | 92.10% | 26.60% |
| Vomiting | - | 35.30% | 10% |
| Motion sickness | - | 50% | 26.60% |
| Positional nystagmus | - | 23.50% | - |
| Positional vertigo | - | - | 70% |
| Gaze induced vertigo | - | - | 56.60% |
| Stress induced vertigo | - | - | 93.30% |
| Lack of sleep | - | - | 70% |
| Falling sensation | - | - | 66.60% |
| Imbalance | - | - | 40% |
| Blurring of vision | - | - | 40% |

Thus, we can see that, including the present study, other studies have also reported a variety of symptoms in individuals with vestibular migraine. Some of these symptoms are not a part of the diagnostic criteria for vestibular migraine by the Barany Society. Thus, reviewing the diagnostic criteria and including some of the most common vestibular signs and symptoms reported in various literature is necessary.

In the present study, we found no significant association between the signs and symptoms exhibited by the vestibular migraine patients and the cVEMP and oVEMP latency and amplitude parameters. We also did not observe any significant association between the duration of the vestibular signs and symptoms and the cVEMP and oVEMP latency and amplitude parameters. Khalil et al. [4] reported no correlation between the age of the patients, duration of migraine, duration of vestibular disease, duration of dizzy spells, and both cVEMPs and oVEMPs response parameters (latencies and amplitudes) in patients with vestibular migraine. The lack of correlation between cVEMP and oVEMP latency and amplitude parameters and lack of association between the signs and symptoms and cVEMP and oVEMP results indicate that the vestibular migraine could be a heterogeneous entity. Among all the episodic vertigo, the vestibular migraine has chameleon features. Such heterogeneity has been explained based on various vestibular test results in individuals with vestibular migraine [35]. In patients with vestibular migraine, there could be differences in damage to the various peripheral and central vestibular structures. Hence, there may not be a correlation between the different test results.

Summary and conclusions

The results of the present study revealed abnormal cVEMP and oVEMP in individuals with vestibular migraine. The results of the study also showed no correlation between cVEMP and oVEMP findings in vestibular migraine patients. Also, there was no association between the signs and symptoms exhibited by the vestibular migraine patients and vestibular evoked myogenic potentials. In the present study, we also reported several signs and symptoms that patients with vestibular migraine exhibit. The results are indicative of a lesion in the sacculocollic and otolith ocular pathway in individuals with vestibular migraine. Vestibular migraine is heterogeneous and thus can exhibit multiple signs and symptoms. The various signs and symptoms seen in patients with vestibular migraine should be documented for better identification of vestibular migraine.

Abbreviations

cVEMP Cervical vestibular evoked myogenic potentials
oVEMP Ocular vestibular evoked myogenic potentials

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Authors' contributions

ASS was involved in data collection and analysis and manuscript writing. SKS was involved in design of the study, data analysis, interpretation of results, statistical analysis, and critical revision of the manuscript.

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None to declare.

Availability of data and materials

All the data generated during the study are contained in this article. Any additional data can be retrieved from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were as per the ethical standards of the institutional research committee. The Institutional Review Board (AIISH ETHICAL COMMITTEE) of All India Institute of Speech and Hearing approved the study (Ref: SH/EC/PhD/AUD-2/2023–24, Date of Approval: 22.09.2023). An informed consent was taken from all the participants prior to the testing.

Consent for publication

All the patients were informed about the objectives of the study. Written informed consent was obtained from all the participants before the assessment.

Competing interests

The authors have no conflict of interest to declare.

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