International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Original Research Article

A Study of Cervical Vestibular Evoked Myogenic Potential (cVEMP) in Indian Adults with Normal Hearing

Dilip Raghavan[1], Sheetal Raina[2], DK Singh[3], Salil Kumar Gupta[2], Vijay Bhalla[4], Abha Kumari[2]

[1]Professor and Head, Dept pf ENT& HNS, Armed Forces Medical College, Pune, Maharashtra, India - 411040
[2]Assistant Professor, [3]Associate Professor,
Department of ENT & HNS, Command Hospital (Eastern Command), Kolkata, West Bengal, India - 700027
[4]Professor, Department of ENT & HNS, Base Hospital (Delhi Cantt), New Delhi, India - 110010

Corresponding Author: Sheetal Raina

ABSTRACT

Introduction – Vestibular Myogenic Potential (VEMP) is a newer modality to partially assess otolithic organs by assessing the functions of saccule and its neural connections. Cervical and Ocular VEMP are being studied extensively for its anticipated objective utility in diagnosing vestibulopathies. With the advent of various techniques of conduct and interpretation of VEMP there is a felt need to obtain and standardise the normative data in Indian population. This observational descriptive study peruses three objectives - Comparison of effect of different stimuli i.e. click vs. short tone burst & unilateral vs. bilateral stimulation in generation of cVEMP; to study the effect of mode of muscle contraction on cVEMP i.e. head lift vs. neck torsion, and, to study age & gender related variations in generation of these potentials.
Methods – 171 healthy adult volunteers between 18-25 years of age with normal hearing were recruited and subjected to cVEMP testing. cVEMP was performed by head lift and neck torsion manoeuvre and with short tone burst (95 dBnHL, 500 Hz) (STB) and clicks and data was recorded and analysed.
Results – Statistically significant amplitudes (in µV) for both waveforms, p13 and n23, were recorded with head lift manoeuvre as compared to neck torsion and STB stimulus as compared to clicks. Latencies of waveform p13 and n23 were significantly shorter for click stimuli compare to Short tone burst stimulus. We found no statistically significant variation in amplitudes and latencies of both waveforms among both genders.
Conclusion – cVEMP can be reliably obtained by both click and short tone burst stimuli in normal hearing individuals. STB stimulus produces morphologically clearer responses with larger amplitudes than click stimuli while Click stimulus elicits a cVEMP with shorter latencies than STB. Head lift manoeuvre was a reliable means of producing Sternocleidomastoid contraction while neck torsion was not. There was no gender variation in terms of amplitudes and latencies of cVEMP waveforms.
***Key Words* –** Cervical Vestibular Evoked Myogenic Potentials, head lift maneuver, neck torsion maneuver, p13-n23, amplitudes, latencies

INTRODUCTION

The sensitivity of the vestibular system to acoustic stimulation is well established. Sound-evoked vestibular symptoms in humans were first described by Tullio in 1929. [1] The human vestibule has preserved an ancestral sound sensitivity and it has been suggested that a reflex could originate from this property, thus inducing cervical muscle micro-contractions secondary to strong acoustic stimulations. This reflex is assumed to originate in the saccule, the afferent pathways being either the vestibulocochlear nerve or the inferior vestibular nerve, and the efferent pathways the vestibulospinal tract. Averaging these muscular responses allows vestibular evoked myogenic potentials (VEMPs) to be obtained.

Rosengren et al reported that VEMP can also be obtained via superior vestibular nerve and can be recorded on extra-ocular muscles. [2] These VEMPs, obtained on extra-ocular muscles were subsequently called as ocular VEMP (oVEMP) and those obtained with sternocleidomastoids, cervical VEMP (cVEMP). Cervical Vestibular evoked myogenic potentials (cVEMPs) are short latency electromyograms (EMG) that are evoked by high-level acoustic stimuli or bone conduction vibration and are recorded from surface electrodes over the tonically contracted sternocleidomastoid (SCM) muscle. [2,3] cVEMP testing can be performed by Air Conduction Sound, which primarily activates the saccule, [4] where a constant short tone burst (95dBnHL, 500 Hz, ramp = 2 ms, plateau = 2 ms) with rarefaction polarity is given with an insert ear phone or with click stimulus given with a tube inserted in external auditory canal. [5] Sternocleidomastoid (SCM) is made contracted with head lift or neck torsion manoeuvre and electromyographic signals are obtained.

The responses consist of two alternatively positive and negative successive waves (p13-n23, p33-n43). It has been established that cVEMP amplitude depends on muscular tension. It has been noted that in healthy subjects the first component of cVEMP (p13-n23) is more consistent than the second. Studies using human subjects with well-documented peripheral auditory vestibular lesions have confirmed the vestibular origin of the response. Colebatch and Halmagyi demonstrated that the cVEMP is abolished following unilateral vestibular neurectomy. [6] The Saccule, which is the lower of the two Otolith organs, has a slight sensitivity to auditory stimuli and this can be measured. This is the basis of cVEMP test.

The purpose of cVEMP test is to determine if the Saccule, one portion of the Otolith apparatus, as well as the inferior vestibular nerve and its central connections, are intact and working normally. cVEMPs can supplement the current test batteries by providing diagnostic information about the Saccule and or inferior vestibular nerve functions. [7] This is a relatively new objective modality of testing vestibular function and negligible normative data exists regarding this test in the Indian population. Hence this study aims to fill this gap in existing knowledge.

MATERIALS AND METHODS

An observational descriptive study was performed at Department of ENT-HNS at a tertiary care center of Pune, Maharashtra, where 171 adult volunteers between 18 years and 25 years of age with normal hearing and having hearing thresholds at or better than 25 dBHL for octave frequencies between 0.5 and 08 KHz on Pure Tone Audiometry were recruited. Individuals with a history of vestibulopathy in the past were excluded from the study.

Methodology –

With aim to study cVEMP response patterns in adults with normal hearing in a subset of Indian population, we had three objectives in mind – Comparison of effect of different stimuli i.e. click vs. short tone burst & unilateral vs. bilateral stimulation in generation of cVEMP; to study the effect of mode of muscle contraction on cVEMP i.e. head lift vs. neck torsion, and, to study age & gender related variations in generation of these potentials.

Volunteers opting for this study and having clinically normal hearing were subjected to Pure tone audiometry, which was performed using a calibrated digital clinical audiometer in an appropriately sound treated room. Those having desired pure tone thresholds (previously mentioned) and fulfilling the inclusion criteria of this study, were enrolled and further subjected to cVEMP testing. Cervical Vestibular Myogenic Evoked Potential (cVEMP) test was performed in alert and awake subjects, who were made to lie supine with two active electrodes placed on upper half of SCM, one reference electrode on suprasternal notch and a ground electrode on forehead. cVEMP was recorded twice in every subject first by contracting SCM bilaterally by maintaining an elevated head in supine position (head lift manoeuvre) and then by rotating head sideways towards one shoulder head down in yaw plane (neck torsion manoeuvre). With stimuli as short tone burst (95 dBnHL, 500 Hz) and clicks, electromyographic activities were recorded using a standard evoked potential testing system and in different settings as per study objectives to compare & correlate differences if any due to type of stimulus i.e. Tone Burst vs. Click, technique of muscle contraction i.e. neck torsion vs. head lift and bilateral vs. unilateral stimulation. Data generated was statistically analysed using SPSS™ ver 25.0. p value <0.05 was considered significant for statistical correlations and analysis.

Statistical methods –

The data from each visit was charted in Microsoft Excel™ spreadsheet and analysed by SPSS 25.0 on a Windows™ based computer. Data was summarized as mean, median and standard deviation for numerical variables, and count and percentages for categorical variables. Two-sample t-tests for a difference in mean involved independent samples or unpaired samples. Paired t-tests were a form of blocking and had greater power than unpaired tests. *p*-value ≤0.05 was considered as statistically significant.

RESULTS

This study included total of 171 volunteers which included 88 males and 83 females. cVEMP was performed on all subjects twice, using both manoeuvres, i.e., head lift and neck torsion for contracting sternocleidomastoid muscle of subject being tested. Amplitudes and latencies of wave p13 and n23 was thus recorded for Short Tone Bursts (500Hz) and Click for each person, first with ipsilateral stimulation of each ear and then bilateral stimulation. Wave morphology was found to be uniformly poor for the recordings obtained with neck torsion method of contracting sternocleidomastoid and test had to be repeated several times on each subject to gain uniformity in data. When amplitudes (in µV) of wave p13 were charted, as seen in Figure 1, more robust waveforms could be obtained by Head lift method and Short Tone Burst stimuli.

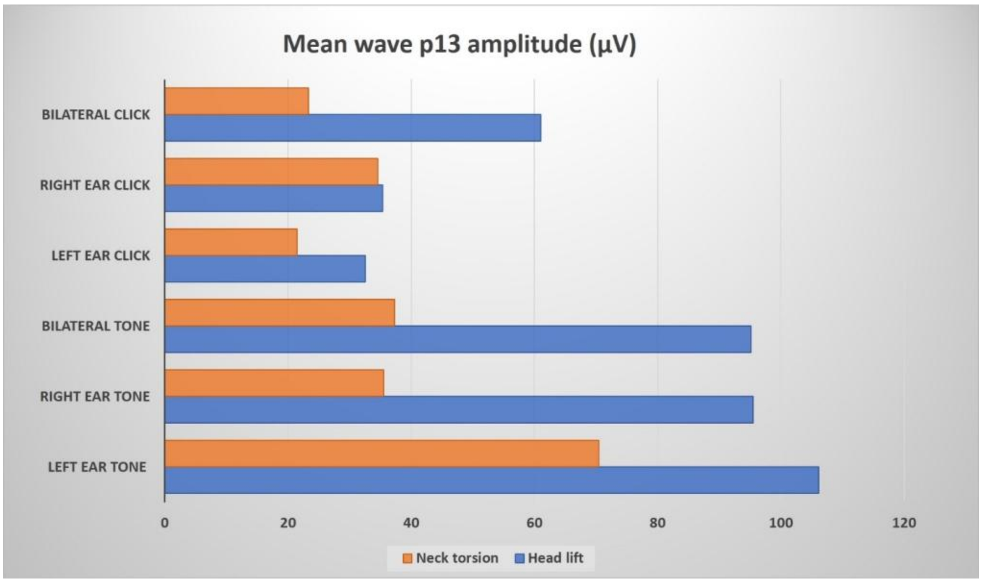

Figure 1: Distribution of amplitudes of waveform p13 in µV

Bird's eye view of Figure 1 and 2 shows patterns of amplitudes (in µV) of waveform n23 were similar to that of wave p13. As seen in Figure 2, robust amplitudes were generated with head lift method and with Short tone burst stimulus.

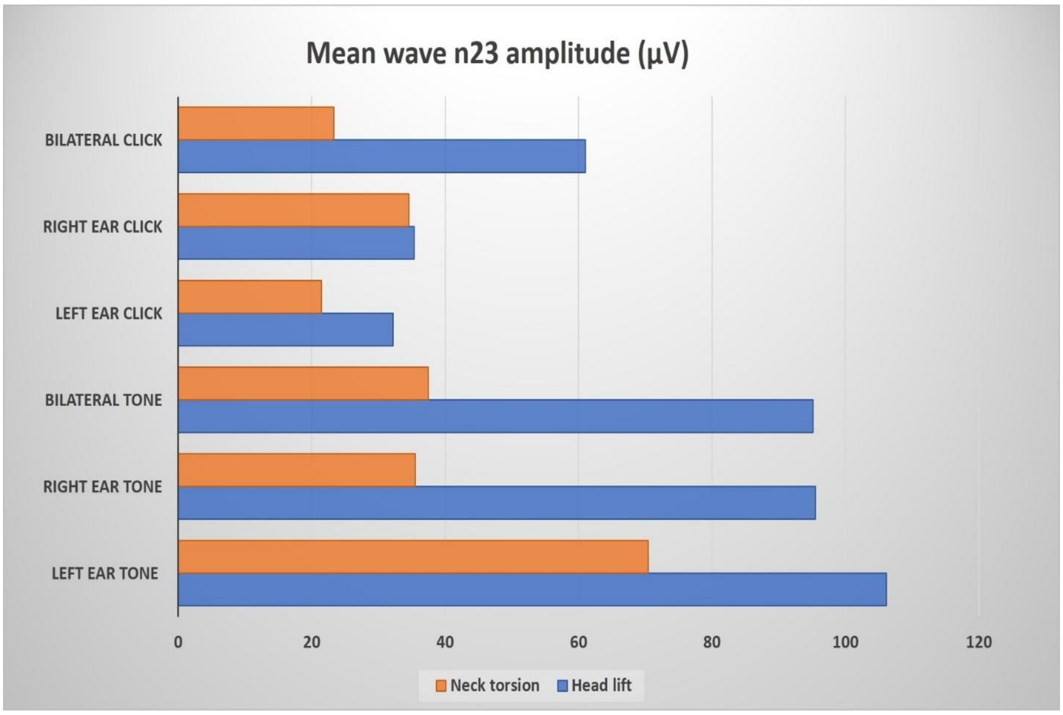

Figure 2: Distribution of amplitudes of waveform n23 in µV

Table 1 compares amplitudes of wave p13 and n23 on head lift and neck torsion manoeuvres on different types and laterality of stimulations.

Table 1 – Comparison of amplitudes of wave P1 and N1 with unilateral and bilateral short tone burst and click stimulation

Stimulus	**Wave p13 amplitudes**				
	Head lift		Neck torsion		p value*
	Mean	SD	Mean	SD	
Left Ear Tone (500Hz)	106.16	43.37	70.47	38.93	<0.0001
Right Ear Tone (500Hz)	95.47	42.23	35.53	28.20	<0.0001
Bilateral Tone (500Hz)	95.13	38.99	37.29	20.65	<0.0001
Left Ear Click	32.57	19.54	21.45	12.69	<0.0001
Right Ear Click	35.34	20.51	34.53	24.56	<0.0001
Bilateral Click	61.02	29.63	23.29	11.74	<0.0001
	Wave n23 amplitudes				
	Head lift		Neck torsion		p value*
	Mean	SD	Mean	SD	
Left Ear Tone (500Hz)	106.16	43.37	70.47	38.93	<0.0001
Right Ear Tone (500Hz)	95.47	42.23	35.53	22.20	<0.0001
Bilateral Tone (500Hz)	95.13	38.99	37.49	20.65	<0.0001
Left Ear Click	32.17	19.54	21.45	12.69	<0.0001
Right Ear Click	35.34	20.51	34.53	24.56	<0.0001
Bilateral Click	61.02	29.63	23.29	11.74	<0.0001

Statistical analysis using two tailed Student's unpaired t test showed that more consistent, robust and statistically significant waveforms could be obtained with head lift manoeuvre than neck torsion one for contracting sternocleidomastoid, with Short tone burst stimuli than click stimuli and on bilateral stimuli. Unilateral stimuli, whether Short tone burst or click, did not yield statistically significant p13 and n23 waveforms. p13 waveforms, however statistically insignificant, were slightly higher than n23 waveforms. In another observation, we found that the amplitudes were uniformly shorter in right ear when patients were subjected to short tone burst stimulation.

On plotting of peak to peak latencies of wave p13 for different stimulus parameters as per objectives, we found that latencies of waveform p13 were significantly shorter for click stimuli compare to Short tone burst stimulus (Figure 3).

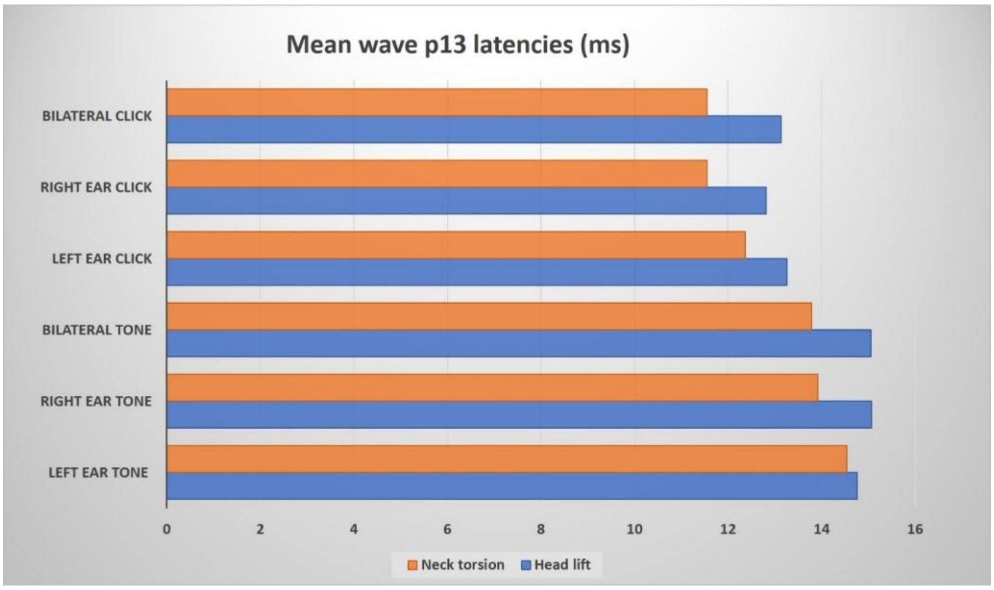

Figure 3: Distribution of peak to peak latencies of waveform p13 in ms

On study of peak to peak latencies of waveform n23, similar results were obtained, i.e., peak to peak latencies were shorter for click stimulus as compared to Short tone burst (Figure 4).

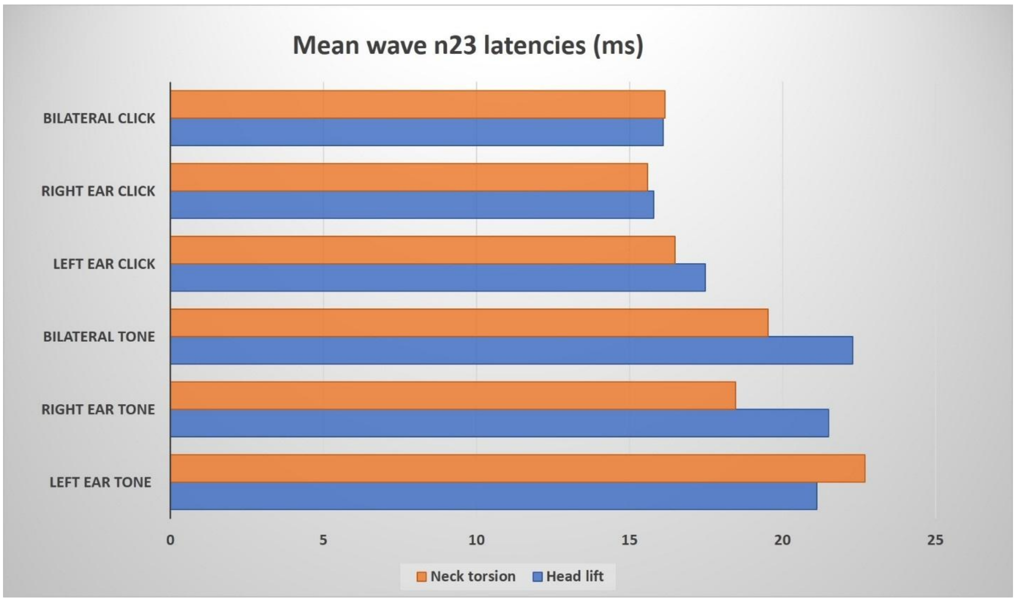

Figure 4: Distribution of peak to peak latencies of waveform n23 in ms.

Detailed comparison of means and SD of peak to peak latencies of both waveforms is as per Table 2. Two tailed hypothesis testing using Student's unpaired t test showed that statistically significant (p value <0.005) shorter latencies can be obtained with click stimulus as compared to Short tone burst stimulus and on bilateral stimulation as compared to unilateral one.

Table 2 – Comparison of latencies of wave P1 and N1 with unilateral and bilateral short tone burst and click stimulation

Stimulus	**Wave p13 amplitudes**				
	Head lift		Neck torsion		p value*
	Mean	SD	Mean	SD	
Left Ear Tone (500Hz)	14.76	2.36	14.54	2.97	<0.0001
Right Ear Tone (500Hz)	15.07	1.78	13.92	2.47	<0.0001
Bilateral Tone (500Hz)	15.06	1.76	13.79	2.31	<0.0001
Left Ear Click	13.26	2.14	12.37	2.93	<0.0001
Right Ear Click	12.81	2.08	11.55	2.18	<0.0001
Bilateral Click	13.13	2.29	11.55	2.29	<0.0001
	Wave n23 amplitudes				
	Head lift		Neck torsion		p value*
	Mean	SD	Mean	SD	
Left Ear Tone (500Hz)	21.13	3.11	22.69	5.06	<0.0001
Right Ear Tone (500Hz)	21.51	3.64	18.46	3.93	<0.0001
Bilateral Tone (500Hz)	22.30	5.16	19.53	3.77	<0.0001
Left Ear Click	17.48	3.13	16.48	3.44	<0.0001
Right Ear Click	15.79	2.43	15.60	2.19	<0.0001
Bilateral Click	16.11	2.58	16.16	3.06	<0.0001

Table 3 - Comparison of gender variation in amplitudes of waveforms p13 and n23 in μV

Stimulus		**Wave p13 amplitudes**				
	Mean Head lift			Mean Neck torsion		
	Male	Female	p value	Male	Female	p value
Left Ear Tone (500Hz)	99.17	94.64	>0.05	62.80	73.37	<0.05
Right Ear Tone (500Hz)	80.20	77.26	>0.05	32.57	31.26	<0.05
Bilateral Tone (500Hz)	90.03	86.25	>0.05	44.44	43.79	<0.05
Left Ear Click	34.98	37.27	<0.05	26.54	25.52	<0.05
Right Ear Click	36.74	37.63	<0.05	27.22	26.00	<0.05
Bilateral Click	49.70	45.85	>0.05	24.21	24.99	<0.05
	Wave n23 amplitudes					
	Mean Head lift			Mean Neck torsion		
	Male	Female	p value	Male	Female	p value
Left Ear Tone (500Hz)	108.42	103.77	>0.05	72.70	67.06	>0.05
Right Ear Tone (500Hz)	103.75	85.54	>0.05	32.02	39.26	<0.05
Bilateral Tone (500Hz)	95.16	95.09	<0.05	39.04	39.84	<0.05
Left Ear Click	28.97	35.58	<0.05	20.58	22.38	<0.05
Right Ear Click	40.29	30.09	>0.05	37.50	31.39	>0.05
Bilateral Click	59.34	62.81	<0.05	22.90	32.71	<0.05

Table 4 - Comparison of gender variation in peak to peak latencies of waveforms p13 and n23 in ms

Stimulus		**Wave p13 amplitudes**				
	Mean Head lift			Mean Neck torsion		
	Male	Female	p value	Male	Female	p value
Left Ear Tone (500Hz)	99.17	94.64	>0.05	62.80	73.37	<0.05
Right Ear Tone (500Hz)	80.20	77.26	>0.05	32.57	31.26	<0.05
Bilateral Tone (500Hz)	90.03	86.25	>0.05	44.44	43.79	<0.05
Left Ear Click	34.98	37.27	<0.05	26.54	25.52	<0.05
Right Ear Click	36.74	37.63	<0.05	27.22	26.00	<0.05
Bilateral Click	49.70	45.85	>0.05	24.21	24.99	<0.05
		Wave n23 amplitudes				
	Mean Head lift			Mean Neck torsion		
	Male	Female	p value	Male	Female	p value
Left Ear Tone (500Hz)	108.42	103.77	>0.05	72.70	67.06	>0.05
Right Ear Tone (500Hz)	103.75	85.54	>0.05	32.02	39.26	<0.05
Bilateral Tone (500Hz)	95.16	95.09	<0.05	39.04	39.84	<0.05
Left Ear Click	28.97	35.58	<0.05	20.58	22.38	<0.05
Right Ear Click	40.29	30.09	>0.05	37.50	31.39	>0.05
Bilateral Click	59.34	62.81	<0.05	22.90	32.71	<0.05

As per our next study objective, we endeavoured to find any gender variation in amplitudes and latencies among both waveforms obtained during cVEMP testing of 88 male and 83 females study subjects. We found high variability and no statistical significance in amplitudes of waveform p13 as well as of n23 when both genders were compared (two tailed Student's t test) (Table 3), although, amplitudes were slightly higher for males than females. Similarly, when peak to peak latencies of both waveforms among genders were compared, trend of shorter latencies was found for females, these results, though, were statistically non-significant (two tailed Student's unpaired t test) (Table 4).

DISCUSSION

Objectively assessing balance functions using electrophysiologic measures is a challenging task. The Caloric test and it's variations like the Electronystagmography (ENG), Computerised Nystagmography (CNG), Video Nystagmography (VNG) have a limitation that they along with Rotational tests, assess only the Semi-circular Canal function. Assessment of the otolith organs and their neural connections has long been an elusive goal. However, measurement of Vestibular Evoked Myogenic Potentials (VEMP) has now made it possible to at least partially assess the Otolith organs by assessing the function of the Saccule and its neural connections. Cervical VEMP is a biphasic response elicited by loud clicks or tone bursts recorded from the tonically contracted sternocleidomastoid muscle. Current data suggest that the VEMP is a vestibulo-collic reflex whose afferent limb arises from acoustically sensitive cells in the saccule, with signals conducted via the inferior vestibular nerve. [7] Literature gives conceding evidence that in healthy subjects the first component of cVEMP, i.e., p13-n23 is more consistent than the second. [8] Binaural stimulation is always responsible for responses of greater amplitude than those obtained from monaural stimulation. Following monaural stimulation, however, cVEMPs generated, are either of greater amplitude on the muscle ipsilateral to the stimulation or of the same amplitude on bilateral muscles. [9] There is consensus in the literature demonstrating that VEMP amplitude depends on stimulus intensity: the threshold of VEMP occurrence is clearly above auditory level but varies from one individual to the next. Likewise, while several studies tend to demonstrate that VEMPs depend on vestibular integrity, others suggest that afferent pathways could be of both cochlear and vestibular origin. Finally, while it has been suggested that VEMP efferent pathways travel through the vestibulospinal tract, whether it is the lateral or the medial vestibulospinal tract that is concerned remains to be clarified. [8-10]

There are various objective and subjective parameters which have been developed for assessment of patients suffering from CRSwNP who have been managed medically as well as surgically. One of the valid criteria used worldwide is Lund and Mackay scoring systems which addresses not only the quality of life but also offers objectivity in terms of endoscopic examination and imaging assessment. [11,12] It includes a quality of life assessment scores in terms of Visual Analogue Scale scoring system [12,13] whose much simplified, modified version being used worldwide has been utilised in this study [11,13] as well as objective (though not without observer bias) endoscopic and radiological scoring.

An experimental study showed that the response amplitude of the VEMP increased with click and tone-burst level, whereas VEMP latency was not influenced by the stimulus level. The largest tone-burst-evoked VEMPs and lowest thresholds were obtained at 500 and 750 Hz. VEMP latency was independent of stimulus frequency when tone-burst duration was held constant. [14]

Wu HJ studied VEMP in twenty-two healthy volunteers (11 males, 11 females; 44 ears), with ages ranging from 17 to 30 years. The VEMP was recorded using 500Hz STB and then click sound stimuli to each ear. Peak to peak latency and amplitudes of p13-n23 waves and VEMP asymmetry ratio (VAR) were obtained for further analysis. He found that the VEMP responses were present in all subjects. The latencies p13 and n23 of STB-VEMP were significantly longer, and the p13-n23 amplitudes were significantly greater for STB-VEMP ($p<0.05$, paired t test), as well. The VAR, however, showed no significant difference between the 2 stimuli. He concluded that the VEMP responses were significantly different between the stimuli of STB and click, and the norms of different stimuli should be established for clinical interpretations. [15] Similar results have been obtained in this descriptive study. In another observation, there was a statistically significant difference in amplitudes of p13, n23 with the right sided responses being smaller than the left for Short Tone Burst Stimulus. Left Tone Burst VEMP causes left SCM Relaxation & right SCM Contraction. This might explain the variation in amplitude due to right sided Musculature being better developed in most subjects. However, for click stimulus, there was no difference between the two sides in amplitude or latency.

A study by Huang TW et al to investigate whether bilateral clicks provide the same information as unilateral clicks, reported that there was a significant difference ($p < 0.05$) in the latencies, but not for the interval and amplitude ($p > 0.05$). [16] Results from our study suggest that bilateral stimulation result in statistically significant and strong amplitudes as well as shorter latencies.

In the endeavour to find gender related difference in VEMP waveforms, literature search found a study by Ochi K et al which concluded that there are no gender-related differences in the VEMP. They however found a significant correlation between age and both the evoking threshold and the p13 and n23 waveform amplitudes of the VEMP, whereas no significant correlation was observed between age and left-right differences of the VEMP in normal subjects. [17] Various authors have studied side differences in VEMP and have found no significant difference between the two sides in normal individuals without vestibulopathy or Cerebellopontine Angle lesions. [17-19] In our study, statistically significant difference in amplitudes of p13 and n23 were not found among males and females. There was a trend towards shorter peak to peak latencies in females, but results were highly variable and statistically insignificant.

Various authors have studied side differences in VEMP and have found no significant difference between the two sides in normal individuals without vestibulopathy or Cerebellopontine Angle lesions. [17-19] Similar results have been obtained in this study as well.

CONCLUSIONS

With review of literature and results of this study, conclusions drawn are as under –

(a) cVEMP can be reliably obtained by both click and short tone burst stimuli in normal hearing individuals.

(b) Short Tone Burst stimulus at 500 Hz produces morphologically clearer responses with larger amplitudes than click stimuli while Click stimulus elicits a cVEMP with shorter latencies than Short Tone Burst stimulus.

(c) There does not appear to be any gender related variations in either the amplitude of latency of cVEMP.

(d) In our study, head lift was a reliable means of producing Sternocleidomastoid contraction while neck torsion was not.

Conflicts of Interests: None declared.

REFERENCES

1. Halmagyi GM, Curthoys IS, Colebatch JG, et al. Vestibular responses to sound. Annals of the New York Academy of Sciences. 2005 Apr;1039:54-67.
2. Rosengren S, Todd NM, Colebatch J. Vestibular-evoked extraocular potentials produced by stimulation with bone-conducted sound. Clin Neurophysiol. 2005;116(8):1938-48.
3. Akin FW, Murnane OD. Vestibular evoked myogenic potentials: preliminary report. J Am Acad Audiol. 2001;12(9):445-52.
4. Murofushi T, Curthoys IS, Topple AN, et al. Responses of guinea pig primary vestibular neurons to clicks. Exp Brain Res. 1995; 103(1):174-8.
5. Yang T-H, Young Y-H. Click-evoked myogenic potentials recorded on alert guinea pigs. Hearing research. 2005;205(1-2):277-83.

6. Halmagyi G, Colebatch J. Vestibular evoked myogenic potentials in the sternomastoid muscle are not of lateral canal origin. Acta Oto-Laryngologica. 1995; 115(sup520):1-3.
7. Zhou G, Cox LC. Vestibular evoked myogenic potentials. Am J Audiol. 2004.
8. Ferber-Viart C, Dubreuil C, Duclaux R. Vestibular evoked myogenic potentials in humans: a review. Acta oto-laryngologica. 1999;119(1):6-15.
9. Welgampola MS, Colebatch JG. Characteristics and clinical applications of vestibular-evoked myogenic potentials. Neurology. 2005;64(10):1682-8.
10. Isaradisaikul S, Strong DA, Moushey JM, et al. Reliability of vestibular evoked myogenic potentials in healthy subjects. Otol Neurotol. 2008;29(4):542-4.
11. Lim M, Lew-Gor S, Darby Y, et al. The relationship between subjective assessment instruments in chronic rhinosinusitis. Rhinology. 2007;45(2):144.
12. Lund VJ, Mackay IS. Staging in rhinosinusitis. Rhinology. 1993;31:183-.
13. Fokkens WJ, Lund VJ, Mullol J, et al. EPOS 2012: European position paper on rhinosinusitis and nasal polyps 2012. A summary for otorhinolaryngologists. Rhinology. 2012;50(1):1-12.
14. Akin FW, Murnane OD, Proffitt TM. The effects of click and tone-burst stimulus parameters on the vestibular evoked myogenic potential (VEMP). J Am Acad Audiol. 2003;14(9):500-9.
15. Wu HJ, Shiao AS, Yang YL, et al. Comparison of short tone burst-evoked and click-evoked vestibular myogenic potentials in healthy individuals. Journal of the Chinese Medical Association: JCMA. 2007 Apr;70(4):159-63.
16. Huang T-W, Cheng P-W, Su H-C. The influence of unilateral versus bilateral clicks on the vestibular-evoked myogenic potentials. Otol Neurotol. 2006;27(2):193-6.
17. Ochi K, Ohashi T. Age-related changes in the vestibular-evoked myogenic potentials. Otolaryngol Head Neck Surg. 2003;129(6): 655-9.
18. Lee SK, Il Cha C, Jung TS, et al. Age-related differences in parameters of vestibular evoked myogenic potentials. Acta oto-laryngologica. 2008;128(1):66-72.
19. Young Y-H, Kuo S-W. Side-difference of vestibular evoked myogenic potentials in healthy subjects. Hearing research. 2004; 198(1-2):93-8.

How to cite this article: Raghavan D, Raina S, Singh DK et.al. A Study of cervical Vestibular Evoked Myogenic Potential (cVEMP) in Indian adults with normal hearing. International Journal of Research and Review. 2019; 6(11):597-605.

******