Assessment of Different Vestibular Pathways in Individuals with Dizziness

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Abstract

Assessment of vestibular system is complex since vestibular system involves multiple numbers of structures. Hence for the assessment of the complete vestibular system multiple numbers of tests are required. Two groups of subjects participated in the present study, Clinical group consists of 15 participants in 3 sub groups with 2 groups having an otological diagnosis and the third group having no otological or neurological diagnosis for vertigo. Sub group A consisted of 8 participants (4 males & 4 females) with Meniere's disease. 7 of the participants had unilateral Meniere's disease and one participant had bilateral Meniere's disease. Sub group B consisted of 5 participants (3 males & 2 females) with unilateral vestibular neuritis. Sub group C consisted of 2 participants (1 male & 1 female) with idiopathic condition. Control group consisted of fifteen individuals (11 males & 4 females) without complaint of dizziness. In control group, the mean latencies of oVEMPs peaks were significantly shorter than mean latencies of cVEMPs peaks. Amplitude of cVEMP peak complex was significantly greater compared to the amplitude of oVEMPs peaks. Also in the contralateral ear of the some participants with Meniere's disease VEMPs results were abnormal. In the sub group B, depending on the involvement of the superior and inferior vestibular nerves the abnormal results were found in ENG, cVEMPs and oVEMPs. No significant association was seen between any of the two tests in both sub group A and B. In the sub group C, the ENG, cVEMPs and oVEMPs results clearly indicate involvement of multiple of anatomical structures.

Keywords: *Dizziness, vestibular functions, VEMP, ENG*

Introduction

Balance may be defined as the capacity to maintain posture and spatial orientation at rest and during movement. The sensory inputs for maintenance of equilibrium comes from three main systems i.e., visual, proprioceptive and vestibular system. Disturbances in any of these systems results in perception of disequilibrium.

The vestibular system is the organ of balance, helps to maintain a balanced position in three-dimensional space. Vestibular stimulation results in three types of reflex responses: vestibulo-ocular, vestibulo-spinal, and vestibulo-collic reflexes. The vestibulo-ocular reflexes help to maintain gaze on a stationary object while the head or body is in motion. Two types of the vestibulo-ocular reflex system are the 'semicircular canal ocular reflex, and the 'otolith ocular reflex' (Bronstein & Gresty, 1991). Vestibulo-spinal reflex is primarily responsible for control of tone in skeletal muscles of the trunk and extremities. Vestibulo-collic reflexes are thought to act on neck muscles in order to stabilize the head, especially during unpredictable movements (Schubert & Shepard, 2008). Any disturbance to these reflexes leads to vestibular dysfunction. Vestibular dysfunction can be peripheral and/or central. Peripheral vestibular dysfunction refers to dysfunction of vestibular end organs or vestibular nerve. Central vestibular dysfunction involves dysfunction of vestibular nuclei, cerebellum, or the occulomotor, vestibulospinal, and proprioceptive pathways.

Assessment of vestibular function includes battery of clinical, electrophysiological and questionnaire based tests. The audiological tests which are administered to assess the vestibular functions are detailed case history, puretone audiometry, immitance measurment, speech audiometry, otoacoustic emissions and auditory brainstem responses, electronystagmography (ENG) and vestibular evoked myogenic potentials (VEMPs).

Current electrophysiological evaluation of the vestibular system, such as ENG, does not assess all functional structures and pathways. ENG battery only assesses lateral semicircular canals and the superior vestibular nerve. By adding cervical VEMPs (cVEMPs) measurements, it is possible to identify any dysfunction in the saccule and/or inferior vestibular nerve.

Another variant of VEMPs are the ocular vestibular evoked myogenic potentials (oVEMPs). oVEMPs are likely to be produced by synchronous activity in the extraocular muscles, i.e., myogenic potentials (Rosengren, Todd & Colebatch, 2005). oVEMPs responses mainly assess the function of otolith organs and superior vestibular nerve.

Studies have reported that the clinical application of ENG (Bergman & Stahle, 1967; Thomas & Harrison, 1971; Wennmo & Pyykko, 1982), cVEMPs (Akkuzu, Akkuzu & Ozluoglu, 2006; Boleas-Aguirre, Sanchez-Ferrandiz, Artieda & Perez, 2007; Murofushi, Shimizu, Takegoshi & Cheng, 2001) and oVEMPs (Chiarovano, Zamith, Vidal & Waele, 2011; Huang, Wang & Young, 2012; Murofushi, Nakahara, Yoshimura & Tsuda, 2011) in various vestibular dysfunction.

cVEMPs are sensitive to disorders affecting saccule or

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the inferior vestibular nerves. cVEMPs in individuals with vestibular symptoms such as "objects spinning or turning around you" have been found to be absent or abnormal (Kumar, 2006). cVEMPs assess only vestibulo-collic reflex pathway whereas ENG assesses the integrity of semicircular canal ocular reflex pathway of the vestibular system. So, addition of ENG with VEMPs may provide valuable information for differential diagnosis in individuals presenting with vestibular dysfunction.

oVEMPs is the new kind of variation of VEMPs responses. Combining oVEMPs and cVEMPs provide complementary information about saccular and utricular otolithic function. Also there is dearth of information regarding oVEMPs recording in the clinical population. So there was need to study the oVEMPs in individuals with vestibular dysfunction.

Equivocal studies are available in the literature regarding the diagnostic significance of ENG in patients with vestibular dysfunction (Coats, 1970; Pflatz, 1984; Ojala, Vaheri & Juntenen, 1989; Colledge, Barr-Hamilton, Lewis, Sellar & Wilson, 1997; Shi, Yu, Niu & Lu, 1997; Bhansali & Honrubia, 1999; Bakr & Saleh, 2000). The equivocal findings might be due to the fact that, earlier tests for assessing the integrity of sacculocollic pathway and otolith ocular reflex pathway were not available thus, there is need to study the integrity of different vestibular pathways (semicircular canal ocular reflex pathway, vestibulo-collic reflex pathway and otolith ocular reflex pathway) using ENG, cVEMPs and oVEMPs in differential diagnosis of vestibular dysfunction.

Equivocal findings also have been reported in association of ENG, cVEMPs and oVEMPs responses in individuals with various vestibular dysfunctions (Chiarovano et al., 2011; Jacobson et al., 2011; Murofushi et al., 2011). Hence there was need to study ENG, cVEMPs and oVEMPs in individuals with vestibular dysfunction. Combination of ENG, cVEMPs and oVEMPs may provide valuable information regarding the pathways involved in different vestibular dysfunction.

Aim of the study

The present study was aimed to assess different vestibular pathways (Semicircular canal ocular reflex pathway, Vestibulo-collic reflex pathway & Otolith-ocular reflex pathway) in individuals with vestibular dysfunction.

Method

Participants

Two groups of subjects participated in the present study, clinical group and control group. Clinical group consists of 15 participants in 3 sub groups with 2 groups having an otological diagnosis and the third group having no otological or neurological diagnosis for vertigo. Sub group consists of 8 participants (4 males & 4 females) with Meniere's disease participated in this study with age range between 18 to 55 years (Mean age = 37 years). 7 of the participants had unilateral Meniere's disease and one participant had bilateral Meniere's disease. Totally 9 ears with Meniere's disease were considered for this study. In sub group B, 5 participants (3 males & 2 females) with unilateral vestibular neuritis with the age range between 34 to 47 years (Mean age = 41 years) participated. In sub group C, 2 participants (1 male & 1 female) with idiopathic condition. The diagnosis of the participant could not be established. The age of the two participants was 34 and 50 years respectively. Fifteen individuals (11 males & 4 females) aged between 22 to 50 years with the mean age of 30 years were served as controls in the present study.

Instrumentation and Test Environment

Pure Tone Audiometry was done to confirm bilateral normal hearing sensitivity. Immittance audiometry was done to rule out middle ear abnormalities. Intelligent Hearing systems (IHS version 4.3.02) was used for recording auditory brainstem responses and air conducted click evoked cervical VEMPs. Biologic navigator Pro EP instrument with biologic insert was used for ocular VEMPs recording. All the audiological tests were conducted in the acoustically treated rooms and noise levels during the testing were within permissible limits (ANSI, 1991). ENG was conducted in a room with low ambient lighting.

Procedure

A detailed case history was taken for each participant prior to testing. It was followed by administration of the dizziness questionnaire. Pure tone audiometry and immittance evaluation was done for all the participants. Then the auditory brainstem responses (ABR) were recorded for both the ears to rule out any retro cochlear pathology. Two channel ABR recording was done for 100?sec click stimuli at 90 dBnHL with the rarefaction polarity. The repetition rate used was 11.1/sec and 90.1/sec. The responses were filtered between 100 Hz to 3000Hz.

During the cVEMPs recordings the participants were instructed to sit straight and turn their head to the opposite side of the ear in which stimulus was presented, so as to activate ipsilateral sternocleidomastoid (SCM) muscle, as it gives reliable and greater amplitude. cVEMPs was recorded using 500 Hz tone burst (2 cycles rise, 0 cycles plateau, and 2 cycles fall, Blackman weighting function) presented at a rate of 5.1/sec using rarefaction polarity. 500 Hz tone burst stimuli was used as the 500 Hz tone burst stimulus gives better amplitude of the cVEMPs (Kumar, Sinha, Bharti & Bar-

Table 1: Recording protocol for Electronystagmography

Band-pass filter	0.1 Hz to 30 Hz
Notch filter	On
Gain	Gain of the incoming signal will be adjusted in such a way that 10 mm deflection of recording pen represents 200 μv of corneoretinal potentials
No. of channels	1
Electrode placement	Non-inverting electrode (+): Outer canthus of the right eye Inverting electrode (-): Outer canthus of the left eye Ground electrode: Lower forehead

man, 2003). The stimuli were presented to the test ear at single intensity of 95 dBnHL using ER - 3A insert ear phones. The responses were recorded for 70 msec post stimulus period along with the 10 msec pre-stimulus period. The recorded responses were then amplified (X 5000) and band pass filtered between 30 to 1500 Hz. The responses were averaged totally for 200 stimuli. cVEMPs was recorded twice to ensure the replicability of the responses.

oVEMPs was recorded for all the participants with upper gaze direction. Participants were instructed to maintain the same upper gaze throughout the test run. Stimuli used to record oVEMPs were identical to stimuli used to record cVEMPs. 500 Hz tone burst (2 cycles rise, 0 cycles plateau, and 2 cycles fall, Blackman weighting function) presented at a rate of 5.1/sec using rarefaction polarity. The stimuli were presented monaurally at single intensity of 95 dBnHL using ER - 3A insert ear phones. 100 stimuli were used for response averaging. The response was analysed for 60 msec post stimulus period. A pre-stimulus period of 10 msec was utilised to record background electrical activity. The recorded electrical responses were amplified (X 5000) and band pass filtered between 1 Hz to 1000 Hz. oVEMPs responses were recorded twice in each ear to ensure replicability of the responses. ENG was recorded with the protocol as shown in Table-1.

Prior to the testing, ENG equipment will be calibrated for each participant. Calibration of the ENG instrument will be done for 10° eye deviation and the input sensitivity of the instrument will be adjusted in such a way that every 10° of eye movement corresponds to 10 mm movement of the recording paper and the 10 mm of paper will move in 1 sec. Two set of tests were administered using ENG system. The details of the test done are shown in Figure-1

Results and Discussion

Vestibular evoked myogenic potentials findings in Control group

Cervical - vestibular evoked myogenic potentials (cVEMPs)

cVEMPs responses could be recorded in all the participants in the control group. In cVEMPs, the latency of p13 and n23 peaks, amplitude of p13-n23 complex and amplitude asymmetry (between the two ears) were analyzed.

Descriptive statistics was done to find out mean and standard deviation for p13 and n23 latencies, amplitude of p13-n23 complex, and inter-ear amplitude asymmetry for p13-n23 complex. The descriptive results of latency, amplitude of p13-n23 complex and inter-ear amplitude asymmetry for p13-n23 complex for the control group is shown in Table 2. Bilateral cVEMPs recordings for one participant in the control group in response to 500 Hz tone burst stimuli presented at 95 dBnHL is

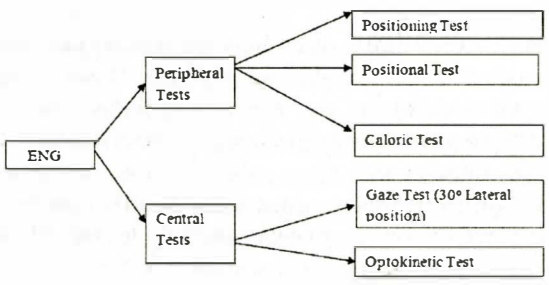

Figure 1: Flow chart of ENG test battery.

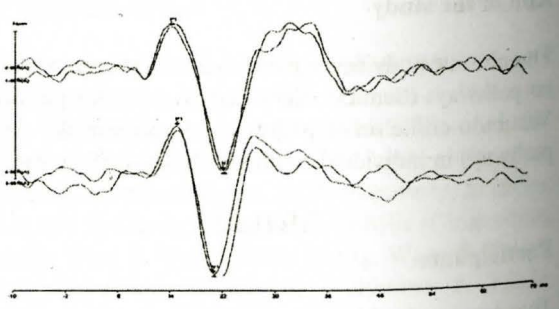

Figure 2: cVEMPs response of one control group participant.

Table 2: Mean and standard deviation (SD) values of latency and amplitude measures of cVEMPs in control group

Parameters	Mean	Standard deviation	Range
p13 latency (msec)	15.10	1.24	12.80 - 17.60
n23 latency (msec)	22.45	2.05	19.20 - 27.20
Amplitude of p13-n23 complex (μv)	40.39	12.66	19.78 - 87.97
p13- n23 complex inter-ear amplitude Asymmetry (%)	14.45	8.71	1.20 - 32.03

shown in Figure 2.

Ocular - vestibular evoked myogenic potentials

Latency of n1, p1 and n2, peak to peak amplitude of n1-p1 and p1-n2 complex, and inter-ear amplitude asymmetry were analyzed in oVEMPs. The oVEMPs could be recorded in all the participants of the control group. Mean and standard deviation of latency of n1, p1 and n2 are shown in Table 3 and amplitude measures are shown in Table 4. The bilateral oVEMPs recordings of one control group participant to 500 Hz tone burst stimuli presented at 95 dBnHL is shown in Figure 3.

Table 3: Mean and standard deviation (S.D) values of latency measures of oVEMPs in control group

Parameters	Mean	Standard deviation	Range
n1 latency (msec)	11.37	0.96	9.91 - 13.20
p1 latency (msec)	16.49	0.90	14.70 - 18.45
n2 latency (msec)	21.83	1.81	18.91 - 27.66

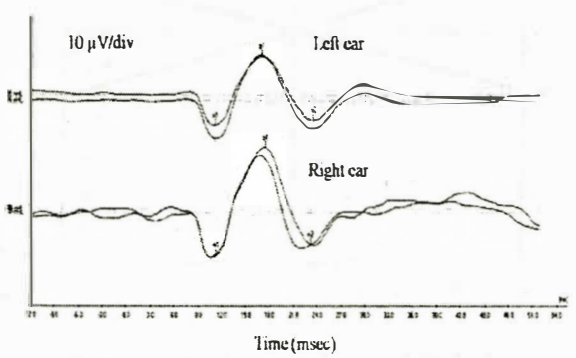

Figure 3: oVEMPs response of one control group participant.

Table 4: Mean and standard deviation (SD) values of amplitude measures of oVEMPs in control group

Parameters	Mean	Standard deviation	Range
Amplitude of n1-p1 complex (μv)	9.02	6.31	1.77 - 23.56
Amplitude of p1-n2 complex (μv)	8.16	5.62	1.46 - 20.54
n1-p1 complex inter-ear amplitude Asymmetry (%)	22.55	15.44	3.00 - 49.35
p1-n2 complex inter-ear amplitude Asymmetry (%)	20.73	12.51	0.68 - 44.49

Correlation between cVEMPs and oVEMPs responses in Control Group

To find out any significant correlation between the latency and amplitude of cVEMPs with latency and amplitude of oVEMPs, a Pearson correlation analysis was done. Pearson correlation analysis revealed a significant correlation between n23 latency of cVEMPs and n1 latency of oVEMPs ($r = 0.496$, $p<0.05$), between n23 latency of cVEMPs and p1 latency of oVEMPs ($r = 0.490$, $p<0.05$) and between n23 latency of cVEMPs and n2 latency of oVEMPs ($r = 0.490$, $p<0.05$). However, Pearson correlation analysis failed to show any correlation between the p13 latency of cVEMPs and p1 latency of oVEMPs ($r= 0.10$, $p>0.05$), p13 latency of cVEMPs and n1 latency of oVEMPs ($r= 0.15$, $p>0.05$), p13 latency of cVEMPs and n2 latency of oVEMPs ($r= 0.20$, $p>0.05$).

Amplitude of p13-n23 complex of cVEMPs did not show any significant correlation with amplitude of n1-p1 complex of oVEMPs ($r = 0.071$, $p>0.05$) and amplitude of p1-n2 complex ($r = 0.042$, $p>0.05$) of oVEMPs. Inter ear amplitude asymmetry of p13-n23 complex in cVEMPs was not significantly correlate with asymmetry of n1-p1 ($r = - 0.508$) or p1-n2 ($r = - 0.186$) complex of oVEMPs ($p>0.05$, Pearson correlation).

The latency of p13, n23 and the p13-n23 amplitude complex of cVEMPs and n1, p1 latency and n1-p1 amplitude complex of oVEMPs obtained in the present study are similar to earlier reports (Akin & Murnane 2001; Akin, Murnane & Medley 2003; Smulders et al., 2009; Chiarovano, et al., 2011; Murnane, Akin, Kelly & Byrd, 2011; Bohra, Sanju & Sinha, 2012). However, in the present study, an additional peak 'n2' in oVEMPs was observed consistently in all the subjects in the control group. The 'n2' peak has not been reported earlier and in the present study the latency of 'n2' was around 22 msec. It is hypothesized that the generators of the

'n2' peak also might be confined in the same anatomical structures from where the 'n1' and 'p1' peak is generated.

Latencies of oVEMPs is shorter compared to the cVEMPs responses and also there was no correlation between the latency of cVEMPs versus latency of oVEMPs. The differences in latencies between cVEMPs and oVEMPs might be due to the differences in length and nerve conduction velocity between vestibular ocular (Broussard et al, 1992) and vestibulo spinal pathways (Uchino et al, 2005) as shown in the animal studies. cVEMPs and oVEMPs responses are generated from different anatomical pathways stimulated by the air conduction stimulation (Chiarovano et al, 2011). cVEMPs responses mainly assess the function of saccule and inferior vestibular nerve, whereas, oVEMPs mainly assess the function of otolith organs and superior vestibular nerve. Pathway involved in the cVEMPs includes the saccular macula, inferior vestibular nerve, the lateral vestibular nucleus, the medial vestibulospinal tract, and the motor neurons of ipsilateral sternocleidomastoid (SCM) muscle (Halmagyi & Curthoys, 1999). The neuronal pathway for oVEMPs via the vestibulo-ocular reflex include, activation of the vestibular nerve and vestibular nucleus, medial longitudinal fasciculus, oculomotor nuclei, ocular nerves and to the contralateral extraocular muscles (Rosengren, et al.2010).

Amplitude of p13- n23 complex was significantly greater compared to the amplitude of n1-p1 and p1-n2 complex of oVEMPs. This is largely due to the differences in the muscle unit content between SCM and extraocular muscles (Park et al, 2010). The muscle thickness is more at the SCM compared to the extraoccular muscles and hence the tonic activation is more for the SCM compared to the extraoccular muscles (Park et al. 2010). Only a weak correlation was found between n23 latency of n1, p1 and n2. Amplitude measures of cVEMPs and oVEMPs did not correlate significantly. This may be due to large variability in amplitude measures of cVEMPs and oVEMPs.

Electronystagmography findings in control group

Central tests

*Optokinetic test:*In control group, all the participants had symmetrical optokinetic responses for visual target moving from right to midline and from left to midline.

Gaze test: In all the participants, there was no nystagmus for either in the left or right 30^{o} lateral position of gaze.

Peripheral tests

Positional test: Out of 15 subjects in the control group, 5 subjects showed some nystagmus beats in one or two head positions, but none of them had presence of nystagmus beats in more than two head positions. Maximum number of nystagmus beats recorded from subjects in the control group in any of the head position was 6 beats/30 seconds.

Table 5: Range of culmination frequency/30 seconds for all four caloric stimulation in control group

Caloric stimulation	Range of culmination frequency per 30 seconds
Right warm	22 - 59
Left warm	20 - 70
Right cold	21 - 51
Left cold	22 - 64

*Positioning test:*Out of 15 subjects in the control group only 3 subjects showed some nystagmus beats in one or two head positions, but none of them had presence of nystagmus beats in more than two head positions. Maximum number of nystagmus beats recorded in positioning test was 8 beats/ 30 seconds.

Caloric test: Bithermal caloric test was recorded from all the subjects in the control group. The culmination frequency was calculated for all the participants in the control group.

In control group, the range of culmination frequency of nystagmus in response to different caloric stimulation is shown in Table 5.

Claussen's butterfly chart was made from the culmination frequency obtained from the participants in the control group. Figure 4 shows a butterfly chart obtained from one of the participants in the control group.

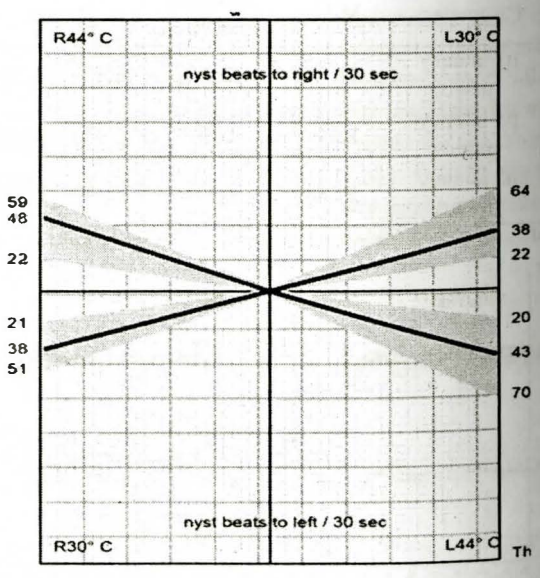

Figure 4: Results of caloric test for one participant in control group as shown in butterfly chart.

Table 6: Clinical information of 7 participants with unilateral Meniere's disease and one participant with bilateral Meniere's disease

				Air conduction thresholds (dBHL)						
S.No	Age (years)	Sex	Ear	250 Hz	500 Hz	1kHz	2kHz	4kHz	8kHz	ABR
1	50	F	Right	15	15	10	10	5	10	N
2	45	M	Right	35	30	35	40	35	40	N
3	26	M	Right	45	40	45	45	50	45	N
4	34	M	Right	55	50	40	45	40	45	N
5	36±	F	Right	35	30	25	25	30	25	N
6	36±	F	Left	45	40	40	35	30	35	N
7	18	F	Left	50	40	40	35	40	40	N
8	55	M	Right	40	35	30	25	25	25	N
9	32	F	Right	45	50	55	50	55	55	N

N - Normal, M-Male, F-Female, ± - Bilateral Meniere's disease, ABR - auditory brainstem response

In the gaze test all the participants of the control group showed no nystagmus in the left or right 30^0 lateral position of the gaze. This was similar to the findings as reported by Kirtane (2009).

Symmetrical optokinetic responses were recorded when the target moves right to midline or left to midline. Symmetrical optokinetic responses are reported in the healthy subjects (Kirtane, 2009). In the present study, none of the participants in the control group showed positional nystagmus with eyes closed condition in more than 2 positions. Isolated occurrences of positional nystagmus with the eyes closed condition in less than 3 positions is seen in some normal individuals (Kirtane, 2009). None of the participants had nystagmus beats in more than 2 head positions and during positioning test, similar findings are considered as normal (Kirtane, 2009).

It should be noted that from the results of caloric tests in the control group caloric responses in two ears and to warm and cold stimulation is not same. Warm stimulation had slightly more number of nystagmus beats compared to the cold stimulation in both the ears. Cold stimulation is reported to be stronger compared to the warm stimulation (Kirtane, 2009). The differences in the results might be due to methodology, type of irrigation and different instruments used in different studies.

Vestibular Findings in Individuals with Meniere's disease

Total 8 subjects (9 ears) in the Meniere's disease group were evaluated using the vestibular evoked myogenic potentials (cVEMPs and oVEMPs) and electronystagmography. 8 subjects had a unilateral Meniere's disease whereas one subject had a bilateral Meniere's disease. In the electronystagmography, both peripheral tests and central tests were administered to the participants. The details of the participants with Meniere's disease are given below in Table 6.

Vestibular evoked myogenic potentials

Cervical - vestibular evoked myogenic potentials

Out of 9 ears (8 participants) with Meniere's disease, 5 ears had absence of cVEMPs responses (55.55%), one ear had reduced peak to peak amplitude (11.11%) and 3 ears had normal responses (33.33%). Kruskal wallis test was performed to see whether the responses for 3 ears having normal cVEMPs responses were similar to the control group. Kruskal wallis test revealed no significant difference between cVEMPs responses latencies of p13 and n23, amplitude of p13-n23 between the control group and the Meniere's disease group ($p>0.05$)

Ocular - vestibular evoked myogenic potentials

In oVEMPs recordings, 7 affected ears showed absent responses (77.78%) and 2 ear showed present oVEMPs response (22.22%). The latency and amplitude of two ears with present oVEMPs was within the range of normal values.

Electronystagmography

Central tests

Optokinetic test: None of the participants in the Meniere's disease group showed any asymmetrical response in the optokinetic test.

Gaze test: All the participants showed no nystagmus in both gaze conditions.

Peripheral tests

Positional test: In 2 subjects with Meniere's disease, there were positional nystagmus present in two head positions, but the nystagmus beats were lesser than that

obtained for the control group in any of the head positions in the present study.

Positioning test :In 3 subjects with Meniere's disease, nystagmus were present in two head positions in the positioning tests, but the nystagmus beats were lesser than that obtained for the control group in any of the head positions.

Caloric test: Out of 9 ears with Meniere's disease, ENG results showed hypo activity in 7 affected ear (77.78%), one ear showed hyper activity (11.11%) and one ear showed normal response (11.11%) to caloric stimulation.

Association of Caloric test, cVEMPs and oVEMPs results in subjects with Meniere's disease

Out of 9 ears with Meniere's disease, 8 ears (88.89%) showed abnormal results in caloric test, 7 ears (77.78%) showed abnormal or absent oVEMPs responses and 6 ears (66.67%) showed abnormal or absent cVEMPs responses.

In 66.67% (6 ears) individuals, there was association of caloric test and oVEMPs findings. 6 ears showed (66.67%) abnormal results in both caloric test and oVEMPs. None of the ear showed normal findings in both the tests. In 33.33% (3 ears) of individuals, there was dissociation of caloric test and oVEMPs responses. Two ear with normal oVEMPs responses showed abnormal caloric test findings, whereas, one ear with normal caloric test showed absent oVEMPs response.

In 55.56% (5 ears) individuals, there was association of oVEMPs and cVEMPs findings. In 4 ears (44.44%) with Meniere's disease, both oVEMPs and cVEMPs were absent. One ears (11.11%) showed normal response in both the test. In 44.44% (4 ears) of the individuals, there was a disassociation between cVEMPs and oVEMPs responses. 2 ears with normal cVEMPs responses showed absent oVEMPs responses. One ear with absent cVEMPs responses showed normal oVEMPs responses. One ear with reduced p13-n23 amplitude of cVEMPs showed absent oVEMPs response.

In 55.56 % (5 ears) individuals there was association of caloric test and cVEMPs findings. 5 ears showed (55.56%) abnormal results in both caloric test and oVEMPs. None of the ear showed normal findings in both the tests. In 44.44% (4 ears) of individuals, there was a disassociation between caloric test and cVEMPs responses. One ear with normal caloric test showed absent cVEMPs responses. 3 ears with abnormal caloric test findings showed normal cVEMPs responses.

To find out any significant association between the Calorics tests and cVEMPs, Caloric tests and oVEMPs, oVEMPs and cVEMPs responses, a Chi square test was done. Chi-square test revealed no significant association between caloric and oVEMPs findings ($p = 0.778$), caloric and cVEMPs findings ($p = 0.667$) and between cVEMPs and oVEMPs findings ($p = 0.583$).

In 55.56% (5 ears) individuals, there was association of oVEMPs and cVEMPs findings. In 4 ears (44.44%) with Meniere's disease, both oVEMPs and cVEMPs were absent. One ears (11.11%) showed normal response in both the test. In 44.44% (4 ears) of the individuals, there was a disassociation between cVEMPs and oVEMPs responses. 2 ears with normal cVEMPs responses showed absent oVEMPs responses. One ear with absent cVEMPs responses showed normal oVEMPs responses. One ear with reduced p13-n23 amplitude of cVEMPs showed absent oVEMPs response.

In 55.56 % (5 ears) individuals there was association of caloric test and cVEMPs findings. 5 ears showed (55.56%) abnormal results in both caloric test and oVEMPs. None of the ear showed normal findings in both the tests. In 44.44% (4 ears) of individuals, there was a disassociation between caloric test and cVEMPs responses. One ear with normal caloric test showed absent cVEMPs responses. 3 ears with abnormal caloric test findings showed normal cVEMPs responses.

To find out any significant association between the Calorics tests and cVEMPs, Caloric tests and oVEMPs, oVEMPs and cVEMPs responses, a Chi square test was done. Chi-square test revealed no significant association between caloric and oVEMPs findings ($p = 0.778$), caloric and cVEMPs findings ($p = 0.667$) and between cVEMPs and oVEMPs findings ($p = 0.583$).

Hypo activity to caloric stimulation in the affected ear is the most common finding in the present study, which is similar to the studies reported in the literature (Bergman & Stahle, 1967). In the present study, 7 out 9 (77.78%) affected ears showed hypo activity in caloric test. Hypo activity in caloric response is due to the damage to the hair cells in the horizontal semicircular canal (Murofushi et al., 2011). Only one subject had hyperactive responses for the caloric test. The hyperactive caloric responses in patients who suffer from Meniere's disease may be a transient phenomenon, caused by fluctuations of the vestibular condition, central compensation, age and/or mental state of the patients (Ikeda & Watanable, 1997).

Another significant finding in the present study was absence of both the cVEMPs as well as oVEMPs in 2 ears and absence of oVEMPs in one ear towards the contralateral side. Studies in the literature showed that second ear involvement in individuals with unilateral Meniere's disease was seen in 31% to 37% of cases (Thomas & Harrison, 1971; Green, Blum & Harner, 1991). Study by Lin et al. (2006) found that 27% of participants with unilateral Meniere's disease showed

Caloric test: Out of 5 ears, 4 ears showed hypo activity to caloric stimulation. Caloric responses in one ear were normal.

Association of Caloric test, cVEMPs and oVEMPs results in individuals with vestibular neuritis

In 60% (3 ears) of individuals, there was association of caloric test and oVEMPs findings. Two ears showed abnormal responses to both the tests. One ear showed normal findings in both the test. In 40% (2 ears) of individuals, there was dissociation of caloric and oVEMPss findings. One ear with normal oVEMPs responses showed abnormal caloric findings, one ear with normal caloric findings showed absent oVEMPs response.

In 60% (3 ears) of individuals, there was association of oVEMPs and cVEMPs findings. 2 ears showed normal responses to both the tests. One ear showed abnormal findings in both the test. In 40% (2 ears) of the individuals, there was disassociation between cVEMPs and oVEMPs responses. One ear with normal cVEMPs responses showed absent oVEMPs responses. One ear with absent cVEMPs responses showed normal oVEMPs responses.

In 20 % (1ear) of individuals, there was association of caloric test and cVEMPs findings. One ear showed abnormal responses to both the tests. In 80% (4 ears) of individuals, there was a disassociation between caloric test and cVEMPs responses. 3 ears with abnormal caloric test showed normal cVEMPs responses. One ear with normal caloric response showed abnormal findings in cVEMPs.

In the present study, 2 ears (40%) with vestibular neuritis showed abnormal findings in cVEMPs. Out of two eras with abnormal cVEMPs, one ear showed absent response and other ear showed reduced amplitude of p13-n23 complex and prolonged n23 latency indicating involvement of inferior vestibular nerve. Previous studies have reported 33.33% (Murofushi et al. 2011) and 39% (Murofushi, et al. 2001) abnormal cVEMPs findings in individuals with vestibular neuritis. In an another syudy in 134 patients with vestibular neuritis, Hong, Yeo, Kim and Cha (2008) found abnormal cVEMPs response in 36.6% of the participants, whereas Chiarovano et al. (2011) reported that 66.67% of participants showed abnormal cVEMPs responses in their study. The findings of the present study are almost similar to the study by Murofushi et al. (2001, 2011). The differences in different study might be due to involvement of different branches of vestibular nerve in individuals with vestibular neuritis (Aw, Fetter, Cremer, Karlberg & Halmagyi, 2001).

oVEMPs responses were absent in 2 ears (40%) indicating involvement of superior branch of vestibular nerve. Other studies have reported 75% (Chiarovano et al. 2011) and 100% (Murofushi et al., 2011) abnormal oVEMPs responses in individuals with vestibular neuritis. Variability in the results of different studies might be due to variable sample size and variable involvement of different branches of vestibular nerve in individuals with vestibular neuritis (Aw et al.2001). Combining the results of cVEMPs and oVEMPs, it can be concluded that the vestibular neuritis can have origin in inferior vestibular nerve alone or can have origin in superior vestibular nerve alone. The abnormal response of either cVEMPs or oVEMPs in individuals with vestibular neuritis is due to the involvement of the vestibular nerve. Individuals with vestibular neuritis have shown degenerative changes in the vestibular neuroepithelium, as well as in the vestibular nerve and the vestibular ganglion as shown in histopathological study of temporal bones in such individuals (Nodal, 1995), which might be a reason for absence of any recordable potentials from the vestibular nerves.

Prolonged latency was found in one participant and that might be due to the lesion at the nerve level which affects the conduction of impulses. Study by Hong et al. (2008) reported 59.2% of participants with prolonged p13 latency and 51% of participants with prolonged n23 latency. However, study by Murofushi et al. (2001) reported that none of the participants showed prolonged latency. The variability in results of different study due to, the variable extent of damage to the vestibular nerve in the participants of the different study.

None of the participants in the present study showed abnormal finding in the central test of ENG indicating involvement of only primary vestibular nerve in affected side, however abnormal central findings in ENG has been reported in the literature (Wennmo & Pyykko, 1982; Corvera & Davalos, 1985) due to the involvement of brainstem and cerebellum (Wennmo & Pyykko, 1982).

One of the participants in the present study had abnormal positional and positioning test findings. Wennmo and Pyykko (1982) reported 21 out of 30 individuals with vestibular neuritis having positional nystagmus, and reported that presence of positional nystagmus does not have any diagnostic significance in vestibular neuritis.

4 out of 5 ears (80%) showed, hypo activity caloric stimulation which is the most common findings reported in the vestibular neuritis (Wennmo & Pyykko, 1982). Hypo activity in caloric test indicates damage to the superior branch of vestibular nerve innervating horizontal semicircular canal (Wennmo & Pyykko, 1982).

Strong association of caloric test and oVEMPs findings have been reported in the literature (Murofushi et al. 2011). In the present study, 60% cases there was association between caloric and oVEMPs findings, 60%

cases had association between cVEMPs and oVEMPs and 20% cases had association between caloric test and cVEMPs finding. However, the chi square test failed to show any statistically significant association between the two tests. The results on chi square test might have got affected because of the smaller sample size of the present study. Probably a larger data would have reflected any significant association.

Vestibular neuritis can involve either superior branch or inferior branch of vestibular nerve or involvement of both the branches, based on involvement of different branch of vestibular nerve, vestibular neuritis can be superior or inferior or total vestibular neuritis (Murofushi et al. 2011).

Caloric test assess the functioning of superior branch of vestibular nerve innervating lateral semicircular canal, oVEMPs assesses majorly the functioning of superior branch innervating utricular macula and cVEMPs assess the functioning of inferior branch innervating saccular macula. Combining the 3 test will help us to determine involvement of different branches of vestibular nerve.

In the present study, one participant had abnormal findings in all 3 tests indicating total vestibular neuritis, one participant had abnormal findings in caloric and oVEMPs and normal cVEMPs responses indicating that inferior vestibular nerve is spared. Another participant had normal findings in caloric and oVEMPs, abnormal findings in cVEMPs responses indicating involvement of only inferior vestibular nerve. Remaining 2 participants had conflicting findings. They had abnormal caloric test results but normal oVEMPs and cVEMPs indicating involvement of superior nerve innervating lateral semicircular canal. Study by Kim et al. (2008) have reported that early recovery from abnormalities occur for otolith organs compared to the semicircular canals after vestibular neuritis. So the above 2 participants might have recovered the functioning of otolith organs with their respective branch of the vestibular nerve. However, such comment needs to be validated with studying recovery pattern of abnormalities of different tests after the onset of vestibular neuritis.

Vestibular findings in Individuals with idiopathic condition

Total 2 subjects (4 ears) in this group participated in this study. The diagnosis of these subjects could not be established by the Neurologist and the otolaryngologists.

Vestibular evoked myogenic potentials findings Individuals with Idiopathic condition

Cervical Vestibular evoked myogenic potentials

cVEMPs responses were abnormal in all 4 ears (100%). In one ear showed prolonged p13 and n23 latencies of cVEMPs. Other 3 ears showed absent cVEMPs responses.

Ocular - vestibular evoked myogenic potentials

Out of four ears, 3 ears showed absent oVEMPs responses (75%). oVEMPs responses was present in one ear and those responses were within normal limits.

Electronystagmography

Central tests

Optokinetic test: Both the participants had symmetrical optokinetic responses. No abnormality was noticed during the recording.

Gaze test:No nystagmus were recorded in right and left lateral gaze condition for both the participants. No abnormality was noticed during the recording.

Peripheral tests

Positional test: No nystagmus was present in positional test for both the participants

Positioning test: Both the participants had no nystagmus in the positioning test

Caloric test: In caloric testing one participant showed

Table 8: Clinical information of 2 participants with idiopathic condition

				Air conduction thresholds (dBHL)						
S.No	Age (years)	Sex	Ear	250 Hz	500 Hz	1kHz	2kHz	4kHz	8kHz	ABR
1	33	M	Right	15	20	15	25	20	25	N
2			Left	5	5	10	10	5	10	N
3	50	F	Right	5	10	5	5	10	15	N
4			Left	10	10	5	15	10	15	N

N - Normal, M - Male, F - Female, ABR - Auditory Brainstem Responses

Table 9: shows the relation between the symptoms exhibited by the individual and caloric, oVEMPs and cVEMPs findings

S. No	Symptoms	Number of subject with symptoms	Abnormal rate in Caloric test (%)	Abnormal and/or absent rate in oVEMPs (%)	Abnormal and/or absent rate in cVEMPs (%)
1	Lightheadedness or swimming sensation in the head	7	85.71	57.14	71.43
2	Blacking out or loss of consciousness	9	88.89	66.67	55.56
3	Tendency to fall.	13	92.31	92.31	61.54
4	Objects spinning or turning around you.	11	90.91	72.73	45.45
5	Sensation that you are turning or spinning inside.	4	100	100	100
6	Loss of balance when walking	13	92.31	76.92	61.54
7	Headache	5	60	60	40
8	Pressure in the head	5	80	60	60
9	Nausea or vomiting.	12	100	75	50

hypo activity to right ear and normal response in left ear stimulation. Another participant showed hyper activity response to right ear stimulations and response to left ear stimulation was normal.

First participant in the subgroup C had abnormal cVEMPs in both ears. Right ear had absent response and left ear had prolonged p13 and n23 latencies. oVEMPs responses was normal in right ear and absent in left ear. Caloric responses were normal in left ear and hypo activity in right ear. This participant had no otological diagnosis for the dizziness. This participant had no history or presence neurological or neuro muscular problems. From the above results it is clear that in this participant functioning of semicircular ocular reflex in right ear, left ear otolith-ocular reflex pathway and bilateral sacculo-collic pathways were affected.

Second participant had absent cVEMPs and oVEMPs responses bilaterally. Caloric test revealed normal response in the left ear and hyperactivity in the right ear. These participants also had no history or presence of any neurological or neuromuscular problems and have no otological diagnosis for dizziness. ENG, cVEMPs and oVEMPs revealed that in this participant functioning of semicircular ocular reflex in right ear, bilateral otolith-ocular reflex pathway and bilateral sacculo-collic pathways were affected.

In the above two participants, the diagnosis could not be established. The results from the above two participants clearly indicate the involvement, of multiple of anatomical structures. Because of the multiple anatomical structures involvement the sign and symptoms exhibited by these clients may be very complex and hence the diagnosis could not be established. The combination of ENG, cVEMPs and two participants, it can be concluded that one particular test may not be able to find out the extent of lesion.

Association of symptoms exhibited by the individuals and test findings

Table 9 shows the relation between the symptoms exhibited by the individual and caloric, oVEMPs and cVEMPs findings. Only the section II of the dizziness questionnaire which contains main symptoms of individuals with dizziness was considered. In the present study, variable amount of association was obtained between the sign and symptoms exhibited by the clients and the different test results. A chi square test was administered to see any correlation between the sign and symptoms and the test results. Chi square test results revealed no significant correlation between any of the sign and symptoms with any of the test results ($p>0.05$), but for the symptom "Tendency to fall" was significantly correlated to the oVEMPs response ($p<0.05$). The lack of statistical association may be due to the small group of participants in the present study Based on these sign

and symptoms exhibited by the client, and the test results obtained in the present study, one can narrow down the site lesion in the diagnosis of peripheral vestibular disorders. For example, the participants with nausea symptoms had 100% abnormal finding on caloric test and 75% abnormal finding on oVEMPs test, but in cVEMPs only 50% of the responses were absent. Since the caloric test and the oVEMPs assess the same superior vestibular nerves, it can be concluded with the above finding that lesions of superior vestibular nerves results in vomiting or nausea sensation in almost all the subjects. Similarly, subjects with subjective spinning sensations had 100% abnormal findings on the entire three test, based on which it can be concluded that the disorders of otolith organs or lateral canal results in spinning sensations. However, this will be very premature to generalize the results of the present study due to a smaller sample size.

Conclusions

Caloric test, cVEMPs and oVEMPs mainly assesses the functioning of semi circular canal ocular reflex pathway, sacculo-collic pathway and utriculo-ocular In vestibular dysfunction, one or more reflex pathways are affected. Since the above 3 tests assess the functioning of 3 different pathways, the combination of caloric test, cVEMPs and oVEMPs provides valuable information regarding localization of lesions in various peripheral vestibular disorders.

- ◇ This study provides information regarding the diagnostic significance of combination of ENG, cVEMPs, and oVEMPs in individuals with different vestibular dysfunction.
- ◇ This study provides basis for selection of the different kinds of vestibular rehabilitation in individuals with dizziness based on the affected reflex pathways.
- ◇ The study will help in identifying the exact site of lesion in subjects with different peripheral vestibular disorders.

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