OCULAR VESTIBULAR EVOKED MYOGENIC POTENTIAL (oVEMP) IN SCHOOL GOING CHILDREN

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DEDICATED TO
THE CHILDREN WITH HEARING
IMPAIRMENT

CERTIFICATE

This is to certify that this dissertation entitled "**OCULAR VESTIBULAR EVOKED MYOGENIC POTENTIAL (oVEMP) IN SCHOOL GOING CHILDREN**" is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration No. 12AUD030). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Dr. S. R. Savithri

Director

Mysore

May, 2014

All India Institute of Speech and Hearing

Manasagangothri, Mysore -570006.

CERTIFICATE

This is to certify that this dissertation entitled "**OCULAR VESTIBULAR EVOKED MYOGENIC POTENTIAL (oVEMP) IN SCHOOL GOING CHILDREN**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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May, 2014

DECLARATION

This dissertation entitled "**OCULAR VESTIBULAR EVOKED MYOGENIC POTENTIAL (oVEMP) IN SCHOOL GOING CHILDREN**" is the result of my own study under the guidance of Dr. Sujeet Kumar Sinha, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

Mysore

May, 2014 Register No. 12AUD030

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Chapter-I

INTRODUCTION

Balance system involves mainly 3 systems- the propeoceptive system, the visual system and the vestibular system. The vestibular system is the organ of balance which helps to maintain the balance of the body in three-dimensional space. There are three types of reflexes which are associated with the vestibular system: vestibulo-ocular, vestibulo-spinal, and vestibulo-collic reflexes. The vestibulo-ocular reflexes help to stabilize the image of any object while the head 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 postural control. Vestibulo-collic reflexes are thought to act on neck muscles in order to stabilize the head, especially during unpredictable movements. Any disturbance to these reflexes leads to vestibular dysfunction.

The vestibular system is important for the development of normal movement reactions, motion, and motor control for postural alignment, balance, and vision. Dysfunction of vestibular system can have a major impact on the child's development. As adults, child can also have balance disorder like childhood paroxysmal vertigo, vestibular neuritis, Meniere's disease and perilymphatic fistula. A retrospective review (duration of 4 years: 2004-2008) of vestibular problem in children in USA shows the prevalence rate of 0.45% (O'Reilly et al. 2010).

Any balance disorder needs a comprehensive assessment before the treatment starts. Since vestibular system contains multiple of anatomical structures, various tests are required to assess the different portions of the vestibular system. The vestibular tests which are utilised for assessment of vestibular systems in adults can also be administered in children as the human labyrinth reaches to the adult size at 17 to 19 weeks of gestation and all the structures of the

vestibular system such as semicircular canal and the otolith organs are developed at the time of birth (Jeffery & Spoor, 2004). The function of the semicircular canal can be assessed by the caloric test. The function of the otolith organs (utricle and the saccule) can be assessed by the vestibular evoked myogenic potentials (VEMPs).

Vestibular Evoked Myogenic Potentials are one of the assessment tools of vestibular assessment test battery. They are recorded from averaged electromyography in response to intense auditory stimuli and are used for the assessment of the otolith function. VEMPs have been recorded from tonically contracted cervical muscles and this approach is called ‘‘cervical VEMPs” (cVEMP). They can also be recorded from extra-ocular muscles in response to loud sound and are termed ‘‘ocular VEMPs” (oVEMP).

Ocular Vestibular Evoked Myogenic Potential (oVEMP) is one of the major assessment tools in assessing the utricular function of the vestibular system. The ocular VEMP (oVEMP) is a recently described, vestibular-dependent reflex recorded from the extra-ocular muscles in humans. It is a short latency potential, composed of extra-ocular myogenic responses activated by sound stimulation and registered by surface electromyography via contralateral extra-ocular muscle activation (Felipe & Kingma, 2014).

oVEMP assesses the functioning of superior vestibular nerve and utricle. It is a short latency vestibular evoked potential with a negative peak near 10 msec (n10) and a positive peak near 15 msec (Todd, Rosengren & Colebatch, 2003). The n10 (it is also named as n1) component response is vestibular in origin and most likely originating from the otolith-ocular pathway (Chihara, Iwasaki, Ushio & Murofushi, 2007; Govender, Rosengren & Colebatch, 2009).

Ocular Vestibular Evoked Myogenic Potentials have been found to be useful in the diagnosis of Menier's disease (Huang, Wang & Young,2011; Taylor et al., 2011; Bao, Xu & Guo, 2013), vestibular neuritis (Manzari et al., 2012; Adamec et al., 2013; Kim et al., 2013;Admec et al., 2014), auditory neuropathy (Sinha et al., 2013), superior semicircular canal dehiscence syndrome (Zuniga, Janky, Nguyen, Welgampola & Carey, 2013), posterior canal benign paroxysmal positional vertigo (Seo, Saka & Sakagami, 2013;Nakahara, Yoshimura, Tsuda & Murofushi, 2013).

Need for the study

- Vestibular evoked myogenic potential is the only tool which assesses the functioning of otolith organ. oVEMP is a recent variation of VEMP which assess the utricular system. There is a dearth of information on oVEMP data in Indian children.
- The thickness of extra ocular muscles increase with age: - 5-10 years: 3.12mm; 11-15 years: 3.60mm; 28-37 years: 4.57mm (Sacca, Polizzi, Macri, Patrone & Rolando, 2000). There is dearth of information on oVEMP data across the different age group in children. Thus, there is need to study oVEMP in different age group in children.
- Some studies show the difference in thickness of extra ocular muscles in Koreans and Japanese (Lee, Lim, Lee, Oum, Kim & Lee, 2001; Takahashi, et al. 2008). So, there is need to study the oVEMP variation in different population including Indian population.

Aim of the study:

- To study the oVEMP in school going children.

Objectives of the study:

- To study the latency & amplitude of oVEMP in children.
- To compare the results of oVEMP between the children and adults.

Chapter - II

REVIEW OF LITERATURE

Balance disorders in children are very difficult to recognize. Children often are unable to describe their symptoms and they may just seem clumsy. The episodes may be of short duration, autonomic symptoms may be prominent, or symptoms may be thought of as a behavioural disorder. Dizziness may indicate a problem in the vestibular system or may indicate a problem in other sensory systems or an abnormality of other organ systems. Management of these disorders depends on an accurate diagnosis. Disorders associated with dizziness in children can be divided into three broad categories: (1) acute nonrecurring spontaneous vertigo; (2) recurrent vertigo; and (3) nonvertiginous dizziness, disequilibrium, and ataxia (Casselbrant & Mandel, 2005).

Children may experience autonomic syndrome, including nausea and vomiting. Acute nonrecurring spontaneous vertigo can be due to labyrinthine concussion, perilymphatic fistula, vestibular neuronitis or acute labyrinthitis. Meniere's disease, migraine-associated dizziness, seizure disorder, periodic ataxia or anxiety may cause recurrent episode of vertigo. While bilateral vestibular loss, otitis media, motion sickness, CNS lesion, psychiatric problems or ocular disorders can result in nonvertiginious dizziness, disequilibrium and ataxia (Casselbrant & Mandel, 2005).

Vestibular system is a complex system, which has several anatomical structures such as semicircular canal, utricle and saccule. One particular test cannot assess all the systems. Particularly, assessment of utricle has been possible because of the oVEMP.

Ocular vestibular evoked myogenic potential (oVEMP)

oVEMP is a newly developed variation of vestibular evoked myogenic potential. It assess the functioning of vestibulo-ocular pathway, mainly the otolith organ of vestibular system. This vestibulo-ocular pathway includes the vestibular nucleus, medial longitudinal fasciculus (MLF), oculomotor nuclei, ocular nerve and contralateral extra-ocular muscles (Rosengren, Welgampola, & Colebatch, 2010). The pathway of vestibulo-ocular reflex is given in figure 2.1.

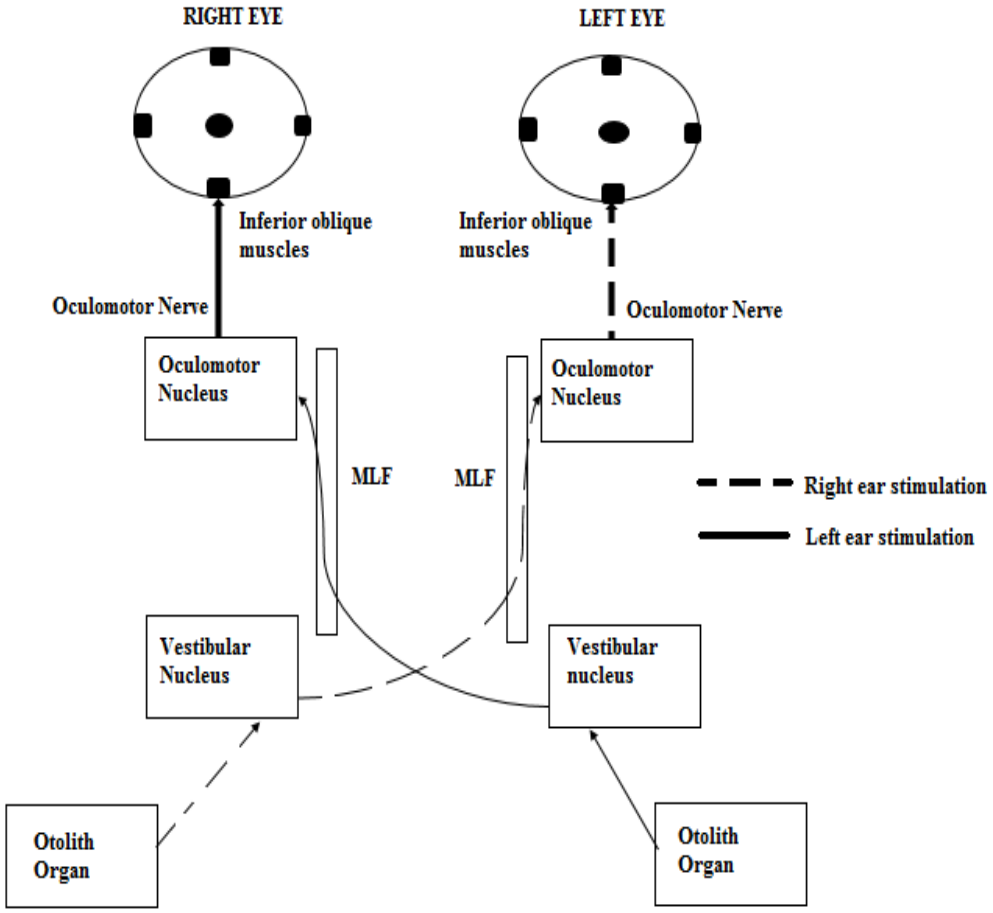


Figure 2.1Neural pathway for ocular vestibular evoked myogenic potential.

oVEMP can be recorded from the extra ocular muscles (maximum contribution from inferior oblique) in response to air-conducted sound, bone-conducted sound or galvanic stimulation (Rosengren et al., 2005; Iwasaki et al., 2007; Todd et al., 2007; Cheng et al., 2010; Curthoys, 2010). oVEMP is an excitatory response and comprises of the initial negative-positive biphasic peaks; n1 at about 10 ms and p1 at about 15 ms after the stimulus onset (Todd et al.,2007; Rosengren et al., 2005). The neuronal pathways for the generation of oVEMP include activation of superior vestibular nerve and the vestibular nucleus, which travels across medial longitudinal fasciculus, to the contralateral occulomotor nuclei, ocular nerves and to extra ocular muscles (Chihara et al., 2007).

As the inferior oblique muscle is the most superficial extra ocular muscle that transverses to the electrode recording site, oVEMP can be obtained easily from the skin surface beneath the eye, contralateral to the acoustically stimulated ear. Additionally, the detection of muscular potential requires upward gazing because belly of the inferior oblique muscle is brought close to the recording electrode and relatively synchronous motor unit activation caused by the inferior oblique muscle contraction can be recorded (Chihara et al., 2007; Govender et al., 2009; Welgampola et al., 2009).

CLINICAL APPLICATIONS OF OVEMP

MENIERE'S DISEASE

The clinical utility of oVEMP in the diagnosis of Meniere's disease has been reported in several studies. Huang, Wang and Young (2011) reported abnormal response of oVEMP in subjects with Meniere's disease. They recorded oVEMP on 30 subjects with Meniere's disease

and found abnormal response in affected ears of 65% of subject with Meniere's disease. They concluded the study by advocating the inclusion of oVEMP in the test battery for the diagnosis of Meniere's disease.

Winter et al., (2011) studied the oVEMP on normal population and population with Meniere's disease. They included 55 subjects without Meniere's disease and 37 patients with Meniere's disease. They used air-conducted sound stimulation (tone-burst, 550 Hz; maximum stimulus level, 120 dB SPL). They reported lower response rate, smaller amplitude, and higher threshold of the oVEMP in patients with Meniere's disease as compared to the normal controls. They also concluded the study by advocating the inclusion of oVEMP in diagnostic workup of patients with possible Meniere's disease.

Bao, Xu and Guo (2013) evaluated the reliability of oVEMP in the subjects with Meniere's disease. They recorded oVEMP on 30 healthy people (control group) and 27 people with Meniere's disease (therapy group). In the therapy group 8 patients had abnormal oVEMP, and 19 had normal oVEMP. They concluded the study by saying that oVEMP test is brief, safe and objective.

Sadhu, Low, Rea and Saunder (2012) recorded oVEMP and cVEMP on 8 healthy volunteers and 12 adult patients with Meniere's disease (8 with definite disease and 4 with probable disease) using tone bursts at 250, 500, 750, 1,000, 1,500, 2,000, 3,000, and 4,000 Hz. They found maximum amplitude using tone burst at 500 Hz in healthy volunteers and this maximum amplitude was shifted towards higher frequency in patients with definite Meniere's disease. The shift was less marked in the patients with probable Meniere's disease. They concluded the study by stating that Meniere's disease ASE is the cause for change tuning response of ear.

Abdeltawwab (2013) reported abnormal oVEMP responses in patients with Meniere's disease. Researcher included 31 patients with definite Meniere's disease and 30 healthy volunteers. He recorded contralateral oVEMP on all the participants and found significantly lower mean amplitudes of contralateral oVEMP and significantly longer mean latencies than that of normal. He concluded the study by advocating the inclusion of oVEMP in the diagnostic test battery for these patients.

Jerin, Berman, Krause, Wagner and Gurkov (2014) reported that the oVEMP 500/1000 Hz amplitude ratio may be a valuable diagnostic tool for Meniere's disease. They included 39 patients with certain Meniere's disease and 19 age-matched healthy controls. oVEMP were recorded using 500 and 1000 Hz air-conducted tone-bursts and 500/1000 Hz amplitude ratio were calculated. They found significant smaller 500/1000 Hz amplitude ratio in affected ear of patients with Meniere's disease as compared to unaffected ear of same patients and ears of healthy controls. They also concluded the study by advocating the inclusion of oVEMP in diagnostic tools of Meniere's disease.

It has been reported that vestibular migraine and Meniere disease behave similarly for most of the VEMP test batteries. These responses can be due to a link in their pathophysiology (Zuniga, Janky, Schubert and Carey, 2012). They reported that 500-Hz tone burst-evoked oVEMP response can differentiate between Meniere's disease and vestibular migraine. Zuniga, Janky, Schubert & Carey (2012) recorded cVEMP and oVEMP using click, 500-Hz tone brust and midline tap stimuli (reflex hammer and mini-shaker) in 20 Meniere's disease patients, 21 vestibular migraine patients and 28 age matched normal. They found reduced click-evoked cVEMP and oVEMP amplitude (relative to controls/normal). Only Meniere's disease group showed reduction in tone-evoked oVEMP amplitude. They reported no difference in oVEMP

with midline tap stimuli. They concluded that tone-evoked oVEMP can differentiate Meniere's disease from controls and from vestibular migraine.

BENIGN PAROXYSMAL POSITIONAL VERTIGO

Talaat et al., (2013) reported abnormal oVEMP response in patients with BPPV. They recorded oVEMP and cVEMP on 32 patients with recurrent benign paroxysmal positional vertigo (BPPV), 80 patients with non-recurrent benign paroxysmal positional vertigo (BPPV) and 100 healthy volunteers with matched age and gender. They found cVEMP or oVEMP abnormalities in 20.5% of the subjects with BPPV (including both recurrent and non-recurrent). 40.3% of subjects with recurrent BPPV showed abnormal oVEMP and cVEMP, while VEMP abnormalities were 12.5% in patients with non-recurrent BPPV. The forms of VEMP abnormalities were absent VEMP (the most prominent form), delayed VEMP and asymmetrical VEMP. They concluded that VEMP abnormalities were detected more in patients with recurrent BPPV suggesting that it may be indicative of the risk of BPPV recurrence.

Studies have revealed that there is a tendency for BPPV patients to show higher rates of abnormal responses of oVEMP bilaterally as well as unilaterally compared with those of cVEMP and caloric tests (Nakahara, Yoshimura, Tsuda & Murofushi, 2013). They recorded oVEMP and cVEMP in 12 patients with BPPV. They reported high percentage of abnormal oVEMP then the cVEMP in patients with BPPV, this shows utricular function in pateints was highly damaged.

Seo, Saka and Sakagami (2013) recorded ocular vestibular evoked myogenic potentials in 13 individuals with BPPV using the 500 Hz tone burst stimuli. They reported that the ocular vestibular evoked myogenic potentials were absent in 11 out of 13 participants with BPPV. However, they also reported that the results of the BPPV improved after administering Epiley's maneuver in these individuals. The authors reported that after the administration of maneuver the

responses were abnormal in only 5 participants. The author's concluded that the oVEMP can be used reliably to detect a utricular lesion in subjects with BPPV.

VESTIBULAR NEURITIS AND LABYRINTHITIS

Abnormal oVEMP responses were reported in subjects with vestibular neuritis and subjects with labyrinthitis in a study done by Moon, Lee, Park, and Lee (2012). The authors recoded oVEMP and cVEMP using 500-Hz tone burst stimuli on patients with vestibular neuritis and acute viral labyrinthitis. They found abnormal cVEMP responses in 20% of patients with vestibular neuritis and 100% of patients with acute viral labyrinthitis and abnormal oVEMP responses in 90% of patients with vestibular neuritis and 100% of patients with acute viral labyrinthitis. They also found positive correlation of oVEMP with caloric test and subjective visual vertical in patients with vestibular neuritis and labyrinthitis.

Admec et al., (2014) studied the role of cVEMP and oVEMP in the follow-up of vestibular neuritis. They recorded oVEMP and cVEMP on 26 patients with the diagnosis of vestibular neuritis at 6 days and 6 months from the onset of the symptoms. Of the 26 patients, 14 showed improvement on oVEMP at month 6 (group 1), and 12 showed no change or worsening on oVEMP at month 6 (group 2). At the same time, there was no change in the amplitudes of the cVEMP on either healthy or affected sides in both groups. The study showed the role of VEMP in the diagnosis and prognosis of patients with vestibular neuritis.

Manzari et al., (2012) studied oVEMP and cVEMP on 59 patients with probable inferior vestibular neuritis. They found asymmetrical p1-n2 component in cVEMP while symmetrical n1 component in oVEMP. In conclusion, they said that sense organ of cVEMP and oVEMP cannot be same, as one response was normal and other was not.

Kim et al., (2013) recorded oVEMP and cVEMP on 30 patients with vestibular neuritis and 45 normal controls using air-conducted sound (ACS) and bone-conducted vibration (BCV). Patients with vestibular neuritisshowed a high proportion of oVEMP abnormalities in response to both ACS (80.0 %) and BCV at the forehead (Fz, 73.3 %) or the mastoid (76.7 %). In contrast, cVEMP were mostly normal with both ACS and BCV in the patients. The results of their study suggest that oVEMP induced by either ACS or BCV appears to depend on integrity of the superior vestibular nerve, possibly due to the utricular afferents travelling in it. In contrast, cVEMP elicited by either ACS or BCV may reflect function of the saccular afferents running in the inferior vestibular nerve.

Abnormal oVEMP has been reported in individual with vestibular neuritis by Shin et al. (2012). They recorded oVEMP and cVEMP in 60 healthy controls and 41 patients with acute vestibular neuritis. Out of 41 patients with vestibular neuritis, 30 patients had superior vestibular nerve involvement, 3 had inferior involvement and 8 had both inferior and superior damaged vestibular nerve. They found normal cVEMP in all 30 patients with superior vestibular neuritis and abnormal oVEMP in all 30 with superior vestibular neuritis. In contrast, the subjects with inferior vestibular neuritis showed normal oVEMP and abnormal cVEMP. They concluded the study by stating that the abnormalities of oVEMP and cVEMP in subjects with vestibular neuritisselectively involving the superior or inferior vestibular nerve suggest that the origin of the vestibular nerve afferents of oVEMP differ from those of cVEMP.

A study on vestibular neuritis done by Govender et al., (2011) showed that AC stimuli were associated with low abnormality rates of cVEMP and high abnormality rates of oVEMP in patient with inferior vestibular neuritis, while in patients with superior vestibular neuritishad high abnormality rates of cVEMP and low abnormality rates of oVEMP. They recorded cVEMP and

oVEMP using air-conducted and bone-conducted stimuli in patients with vestibular neuritis. They found abnormal AC evoked cVEMP, significantly less than for AC evoked oVEMP (cVEMP: 22% vs oVEMP: 68%). Lateral impulses showed high rates of abnormalities (74% vs 70%) for both reflexes. Although forehead taps produced low rates of abnormalities for both reflexes (33% vs 13%), response amplitudes were smaller from the affected ear.

SUPERIOR SEMICIRCULAR CANAL DEHISCENCE SYNDROME

Superior canal dehiscence syndrome (SCD) is caused by the loss of the bony covering overlying the superior semicircular canal. In SCD, oVEMP are characterized by significantly larger amplitudes and lower thresholds (Rosengren et al., 2008). In this study, ACS oVEMP amplitudes larger than 5 mV were measured in 7 of 10 SCD ears but in none of the healthy controls, revealing a sensitivity of 0.7 and a specificity of 1.0 in this small group of SCD patients. Thresholds differentiate SCD patients from healthy subjects particularly when using ACS. Contralateral amplitudes are enlarged in both oVEMP and cVEMP evoked by both ACS and BCV. There is a significant correlation between the size of the dehiscence and oVEMP amplitudes (Manzari et al., 2012).

AUDITORY NEUROPATHY

Auditory neuropathy is a disorder characterized by abnormal 8th functioning with normal OHCs functioning. Sinha, Shankar and Sharanya (2013) reported high percentage of absent oVEMP in persons with auditory neuropathy. They administered cVEMP and oVEMP in 11 patients with auditory neuropathy. They found, oVEMP were absent in 100% of the participants whereas cVEMP were absent in 90.90 % of participants. They concluded that there is high incidence of vestibular involvement in persons with auditory neuropathy spectrum disorders. They also advocated the necessity of inclusion of cVEMP and oVEMP in vestibular test battery used to assess persons with auditory neuropathy spectrum disorders.

OTHER DISORDERS AND APPLICATIONS

Haung and Young (2012) reported the significant abnormal oVEMP in the lesion ears (facial paresis) under the eyes up condition compared to the healthy ears. They recorded oVEMP on 20 patients with unilateral facial paresis. They found that the rate of abnormal oVEMP tests in the lesion ear was 30%, significantly higher than the 0% in opposite healthy ear. They also justified that it is affected ears, and not the eyes, which are responsible to the abnormal oVEMP.

Tseng and Young (2013) studied the utility of audiometry, and cVEMP, oVEMP and caloric tests in the diagnosis of patients with Noise induced hearing loss. They included 30 subjects with NIHL and 30 age and gender matched normal controls. They found abnormal percentage of audiometry, and cVEMP, oVEMP and caloric tests (100, 70, 57 & 33% respectively) which was significantly higher from 13, 13, 7 and 3% in normal controls, respectively. They concluded the study by stating that the decreasing order of abnormal percentages in the function of cochlea, saccule, utricle and semicircular canals after chronic noise

exposure further indicates that the cochlea and saccule is more susceptible to nose exposure than the utricle and semicircular canals.

A study by Bremova, Bayer, Agrawal, Kremmyda, Brandt, Teufel and Strupp (2013) showed a transient increase of oVEMP amplitudes in the affected ear after successful laboratory manoeuvres which can lead to a repositioning of otoconia to the utricle and no changes in cervical VEMP (cVEMP) amplitudes.

OCULAR VESTIBULAR EVOKED MYOGENIC POTENTIAL IN CHILDREN

A study 'Vestibular Evoked Myogenic Potentials in Young Children: Test Parameters and normative Data' by Kelsch, Schaefer & Esquivel (2006) concluded that VEMP is a well-tolerated test for screening vestibular function in young children, performed with minimal test time and reproducible results. Mean latencies in this study suggested a shorter initial negative peak (n2) than in adult studies, consistent with prolongation seen in previous research on the effects of age.

Wang, Hsieh and Young (2013) reported that oVEMPs are not present in infants, but it is present in children of age more than 2 years who can walk like adult. The authors included 20 full-term new-borns (group A), 15 children aged 1 to 3 years (group B), and 15 children aged 4 to 13 years. Auditory brainstem response or audiometry, and oVEMP test were administered on each of the children. They reported absence of typical oVEMP waveform in 20 new-borns, but oVEMP was present in 6 (40%) children aged 1 to 3 years (out of 15) and in all (100%) children aged 4 to 13 years. They concluded the study by stating that maturation of the otolithic-ocular reflex is important to balance control, which is very much necessary for independent gait.

Age related changes in ocular vestibular evoked myogenic potentials via galvanic vestibular stimulation and bone conducted vibration modes was studied by Chang, Young and Cheng (2012). They recorded oVEMP in 69 healthy subjects (aged 22-69 years). 69 subjects were divided into 5 groups of 12-19 subjects. They found no significant difference with galvanic vestibular stimulation among the all age groups whereas there was significant difference (lower amplitude and longer latencies of n1 and p1 peaks) among the age group especially in the under-60 groups.

Hsu, Wang and Young (2009) compared ocular vestibular-evoked myogenic potentials using air conducted sound stimulation in children and adults. They recorded oVEMP on 15 healthy children (aged3-13 years) and 15 healthy adults (aged 24-33 years). They found no significant difference in mean n1 latency, p1 latency and amplitude of oVEMP between children and adults.

Chou, Hsu and Young (2012) studied the oVEMP in children using the bone-conducted vibration stimuli. They recorded oVEMP on 15 healthy children aged 3-14 years and 18 healthy adults aged 24-28 years. They found no significant difference between the children and adults. They concluded the study by stating that oVEMP can be a quick and simple test for investigating the integrity of the VOR system.

All these studies on children have been done on western population. It have been reported that various audiological findings vary in different population. Hence, this study was conducted in Indian population.

Chapter-III

METHOD

The study was conducted with an aim of studying the ocular vestibular evoked myogenic potentials in school going children.

Participants:

The participants in the present study were divided into the three groups.

GROUP I: 15 participants in the age range between 9-11 years.

GROUP II: 15 participants in the age range between 11-13 years.

GROUP III: 15 participants in the age range between 18-30 years.

Participants' selection criteria for all three groups:

- The participants did not have complaint or history of any vestibular problems (dizziness, vertigo, tinnitus or headache).
- The participants did not have any history or presence of any otological problems (like ear discharge, ear pain or itching sensation).
- The participants had pure tone hearing threshold within the normal limit i.e, within 15 dB HL (Clark's criterion, 1981) for octave frequency between 250 Hz to 8000 Hz for air conduction and 250 to 4000Hz for bone conduction.
- The participants had 'A' type tympanogram with presence of acoustic reflex in both the ears for 500 Hz, 1000Hz, 2000 Hz & 4000 Hz for ipsilateral as well as contralateral stimulation.

- All the participants had the Uncomfortable level (UCL) greater than 100 dBHL for speech in both ears.
- The participants did not have any retro-cochlear pathology (space occupying lesion), any neurological problems or neuromuscular problems (based upon the report obtained by the auditory brainstem response and neurologist report).

Instrumentation:

- Calibrated two channel diagnostic audiometer (GSI- 61 audiometer, GrasonStadler, Eden Prairile, USA) with TDH 39 headphone (Telephonics, Farmingdale, NY, USA) housed in MX-41/AR ear cushions and a B-71 bone vibrator (Radioear, KIMMETRICS, Smithsburg, MD, USA) were used for threshold estimation and for finding out UCL for all the participants.
- Calibrated immittance meter (GSI Tympstar, GrasonStadler, Eden Prairile, USA) was used for carrying out tympanometry and reflexometry.
- Biologic Navigator ProEP instrument (Natus Medical Incorporated, Illinois, USA, version 7.0.0) was used for recoring ABR.
- Biologic Navigator ProEP instrument (Natus Medical Incorporated, Illinois, USA, version 7.0.0) were used for recording ocular VEMP. Calibrated Insert ear phones (Biologic system Corp) was used to deliver stimuli.

Test Environment:

All the audiological tests were conducted in the acoustically treated rooms and noise levels during the testing were within permissible limits (ANSI, 1991).

Procedure:

Case history: A detailed case history was taken from all the participants to rule out the history of otological, vestibular or neurological problems.

Otoscopic examination: Otoscopic examination was done for all the participants to rule out any wax, foreign body or infection in the ear canal.

Pure tone audiometry: Pure-tone thresholds was obtained for both the ears using modified version of Hughson and Westlake procedure (Carhart and Jerger, 1959) at octave frequencies between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction.

Uncomfortable level: Ascending method was used to determine participant's UCL for both ears using speech stimuli which were presented through TDH-39 headphones.

Tympanometry: Immitance audiometry was carried out with a probe tone frequency of 226 Hz. Ipsilateral and contralateral reflexes were measured for 500, 1000, 2000, 4000 Hz for both ears.

Auditory brainstem evoked responses: Two channel ABR recording was done for all the participants using click stimuli of 100µsec duration presented at 90 dB nHL in rarefaction polarity. Total 2000 sweeps were used for recording with repetition rates of 11.1/sec and 90.1/sec. The gain settings of the ABR recording were kept as 100,000 with a filter setting of 100

– 30000 Hz. Notch filter was kept on throughout the recording. ABR was recorded twice to ensure the replicability of the waveforms

Ocular VEMP recording: The electrode sites were cleaned with abrasive gel prior to the VEMP recording. The silver chloride disc type electrodes were used along with appropriate conduction gel. The non-inverting (positive) electrode was placed 1cm inferior to the eyelid whereas the inverting (negative) electrode was placed 1cm inferior to the non-inverting electrode. The ground electrode was placed on the lower forehead. Surgical tape was used to keep the electrodes on respective sites to avoid any kind of movement during acquisition. oVEMP was recorded for all participants in upper gaze direction and contralateral mode. The participant was asked to sit straight with the upward gaze. A point on the wall was given to the subject to look during the recording without or little blinking of eye. The oVEMP was recorded for the both eyes from all the participant of experimental as well as control groups. The recording protocol for oVEMP is given below in table-3.1

Table-3.1

Recording protocol for ocular VEMP

Parameters	**Acquisition Parameters**	Parameters	**Stimulus parameters**
Filter Setting	High pass: 10 Hz Low pass: 1000 Hz	Stimulus	Tone Burst
Analysis time	70 msec. including 10 msec. Pre-stimulus recording	Duration of stimulus	2-0-2 cycle
Notch filter	Off	Polarity	Rarefaction
Gain	5000 times	Repetition rate	5.1
No. of channels	01	Intensity	125 dB SPL
Electrode placement	Inverting electrode (-):- inferior of lower eyelids. Non-inverting electrode (+):- immediately inferior to the inverting electrode. Ground electrode:- lower forehead.	Total number of stimulus	150

Data Analysis

In all the recorded waveform three peaks were marked. The first peak which is a negative peak and which occurred around a latency of 10 msec was marked as n1, the first positive peak which occurred around 14-15 msec was marked as p1 and second negative peak which occurred around 20 msec was marked as n2 peak. The representative waveform is shown in figure 3.1

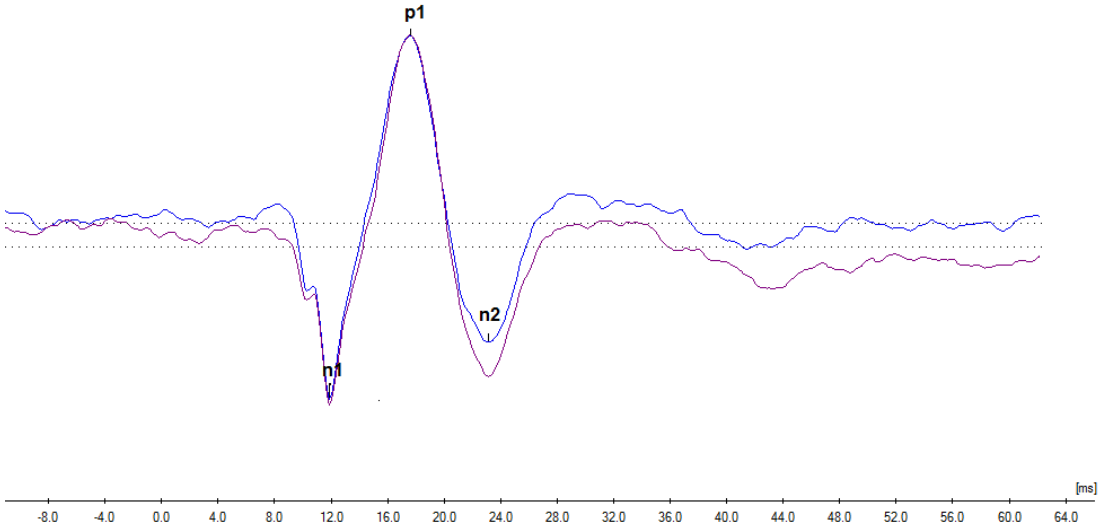


*Figure 3.1*Representative waveform used for analysis of oVEMP

Following analysis was done:

- Absolute latency of n1, p1 & n2 were noted for all the participants from all the three groups.
- Amplitude of n1- p1 complex &p1-n2 were noted for all the participants from three groups.

Chapter – IV

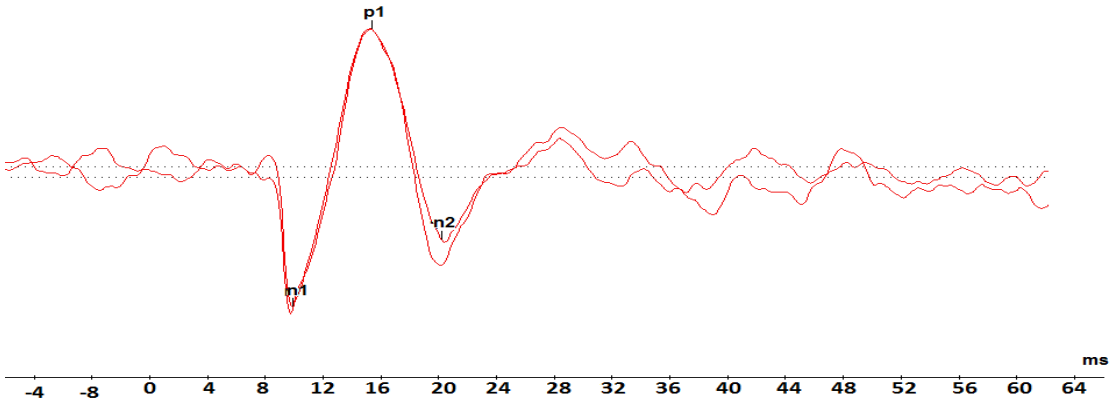
RESULTS AND DISCUSSION

The present study was undertaken with the aim of characterizing the oVEMP in school going children. In specific, the objectives of the study were to find out the latency and amplitude of oVEMP in school going children and compare the same with the normal hearing adults. For all the subjects the latency of n1, p1, and n2 was noted. Also, the amplitude of the n1-p1 complex and p1-n2 complex was noted for all the groups. SPSS version 20.0 software was used for the statistical analysis. Following statistics were carried out.

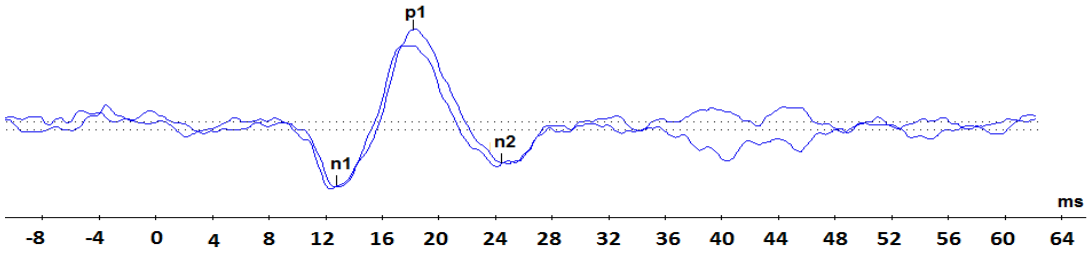
- Descriptive statistics was done to find out the mean and the standard deviation for latency of n1 peak, p1 peak and n2 peak for all the three groups.
- Descriptive statistics was done to find out the mean and the standard deviation for the amplitude of n1-p1 & p1-n2 complex for all the three groups.
- Repeated measure ANOVA was done to see the overall effect of groups and ear on latency of n1 peak, p1 peak and n2 peak.
- Duncan's post hoc test was done to see the group differences.
- Repeated measure ANOVA was done to see the overall effect of groups and ear on amplitude of n1-p1 peak and p1-n2 peak.
- Duncan's post hoc test was done to see the group differences.
- Multiple analysis of variance was done to see the overall group differences for latency of n1 peak, p1 peak and n2 peak and amplitude of n1-p1 peak and p1-n2 peak.
- Duncan's post hoc test was done to understand group wise differences for different peaks.

The representations of waveform for all the groups are shown in figure 1.

a)



b)



c)

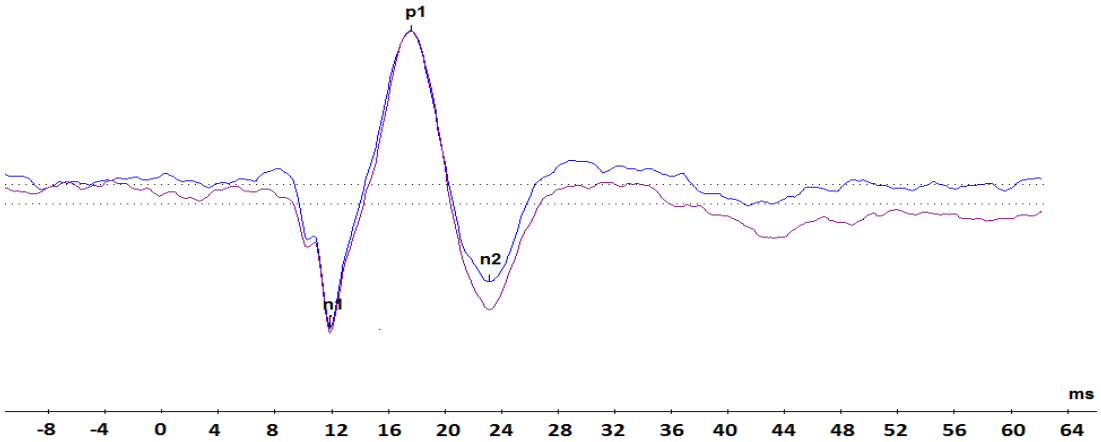


Figure 4.1 **(a)** waveform of one of the children of Group I, **(b)** waveform of one of the children of Group II, and **(c)** waveform of the adult of the Group III.

Latency of oVEMP

The ocular VEMP responses were recorded from both the ears of all the participants from all the groups. The latency of n1 peak, p1 peak, and n2 peak were measured. Descriptive statistics was done to find out the mean and standard deviation for latency of n1, p1 and n2 peak. The mean and the standard deviation for n1 latency, p1 latency and n2 latency for all three groups are given in table 4.1.

Table 4.1

Mean and standard deviation of latency of peaks n1, p1 & n2 of all three Group of both ears

Parameter		**n1 peak**		**p1 peak**		**n2 peak**	
		Mean	SD	Mean	SD	Mean	SD
Group I	Left	12.85	2.67	18.48	2.50	22.69	3.12
	Right	12.92	2.56	17.97	3.09	22.27	2.94
Group II	Left	12.15	1.42	17.09	1.50	21.89	1.36
	Right	11.64	1.21	16.78	1.18	21.18	1.14
Group III	Left	11.94	1.25	17.32	0.94	21.64	1.72
	Right	11.68	1.21	16.83	1.12	20.77	1.47

It can be seen from the table 4.1 that latency of n1, p1 and n2 decreases as the age increases. It can also be seen that the latency of all the peaks (except n1 of I group) is early for

right ear as compared to the left ear. To understand the overall effect of groups on n1, p1 and n2 latencies a repeated measure ANOVA with group and ear as between the subject factor was done. Repeated measure ANOVA revealed a significant main effect for groups [$F(2, 84) = 3.73$, $p < 0.05$], but Repeated measure ANOVA failed to show any significant main effect for ears [$F(1, 84) = 1.32$, $p < 0.05$]. Repeated measure ANOVA also revealed no significant interaction between the groups and ears [$F(4, 168) = 0.44$, $p < 0.05$]. Since, group showed significant main effect in repeated measure ANOVA, Duncan's Post Hoc was done to understand the group differences for the peak latency. Duncan's Post Hoc results are given in table 4.2.

Table: 4.2

Duncan's Post Hoc results to understand the group difference.

Groups	Group I	Group II	Group III
Group I		**p< 0.05**	**p< 0.05**
Group II			p> 0.05

It can be seen from table-4.2 that only group I differed from group II and group III. Further there was no significant difference between group II and group III. Since, the ear did not show a significant main effect, data from the two ears were combined. The mean and S. D of the combined data were calculated in descriptive statistics and the result is shown in table 4.3.

Table 4.3.

Mean and standard deviation of latency of n1, p1 & n2 peaks (combined data from two ears)

Parameters	**Group I**		**Group II**		**Group III**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
n1 latency (msec)	12.88	2.57	11.89	1.32	11.81	1.22
p1 latency (msec)	18.22	2.78	16.93	1.33	17.07	1.04
n2 latency (msec)	22.48	2.99	21.54	1.29	21.21	1.63

It can be seen from table-4.3 that combined mean latency of both ears are more for the group I compared to group II and group III. Further it can also be seen that for n1 and p1 peaks the latency is less for group II compared to group I and III. The figure 4.2 illustrates the combined mean latency of n1, p1 and n2 peaks in all the three groups.

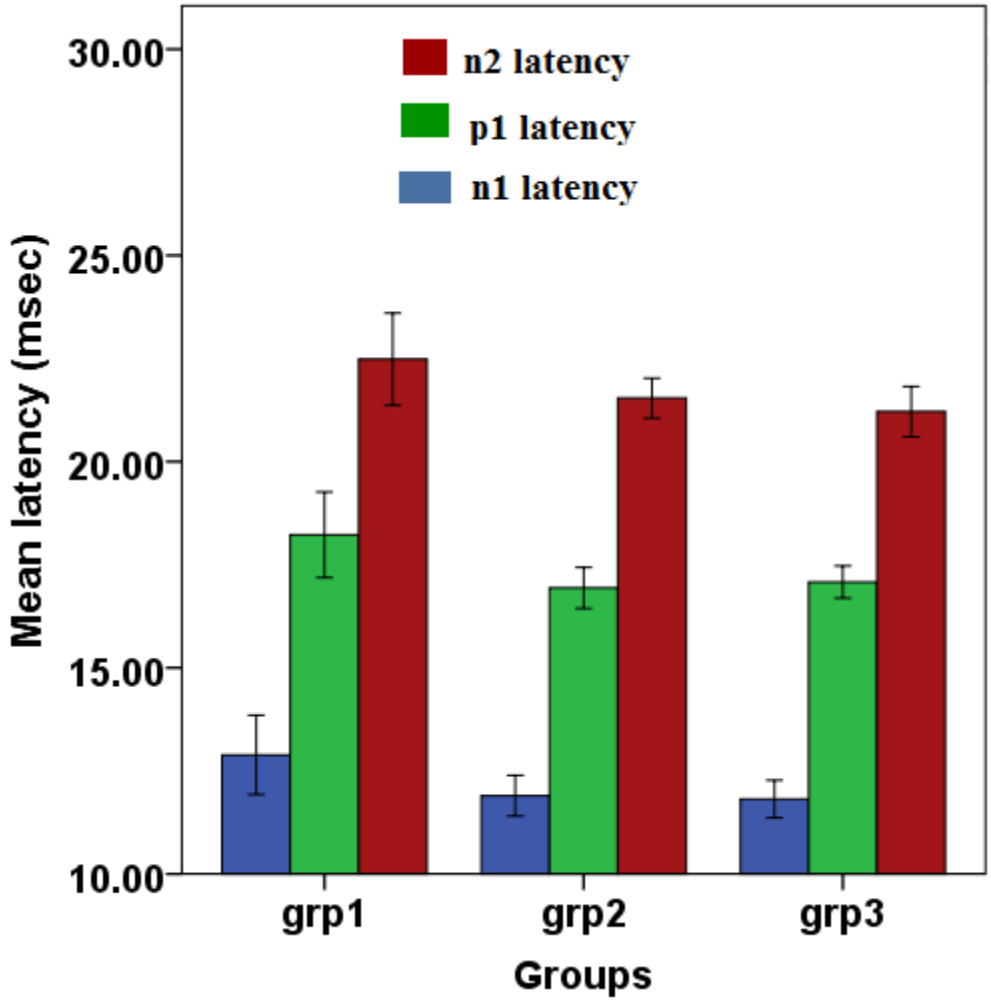


Figure 4.2.Latency of n1, p1 and n2 peak (combined data from two ears)

MANOVA was done to see the group effect on latency of each peak separately.MANOVA showed significant main effect for thelatency of n1 peak [F (2, 87) = 3.23, $p < 0.05$] and the latency of p1 peak [F (2, 87) = 4.24, $p < 0.05$], whereas it showed no significant main effect for the latency of n2 peak [F (2, 87) = 2.95, p = 0.05].Duncan's Post Hoc was done to understand the group difference for the latency of each peak. Duncan's Post Hoc results are given in table 4.4.

Table 4.4.

Duncan's Post Hoc test results for groupwise differences

	n1 peak latency (msec)		p1 peak latency (msec)		n2 peak latency (msec)	
	Group I	Group II	Group I	Group II	Group I	Group II
Group I		**p < 0.05**		**p < 0.05**		p > 0.05
Group III	**p < 0.05**	p > 0.05	**p < 0.05**	p > 0.05	**p < 0.05**	p > 0.05

It can be seen from table-4.4 that latency of n1, and p1 was significantly different for group I compared to group II and III. However, there was no significant difference in latency of n1 and p1 between group II and group III. It can also be seen that n2 latency was significantly different between group I and group III.

Studies related to oVEMP in children have just started to appear. Hsu, Wang and Young (2009) recorded oVEMP in 3- 13 year old children 24-33 years old adults and they found no significant difference in latency of n1 or p1 or n2 peaks of oVEMP between children and adults. The authors concluded that the oVEMP is matured in children by 3 years of age.

Chou, Hsu and Young (2012) reported similar finding in children of age 3-15 years and adults aged between 24-28 years. Wang, Hsieh and Young (2013) studied oVEMP on infants and children. They found that oVEMP was absent in the infants while it was present in all the children of age range 4-13 years. Wang et al. also concluded that at the age of 4 years the responses of the children is adult like.

However, present study shows different results compared to the previous studies reported in the literature. In the present study, 9-11 years children had significant difference in latency of oVEMP compared to 11-13 years and 25-40 years age range. The latency of 9-11 years old

children old was more compared to the 11-13 year old children and adults. This implies that the oVEMP is not matured in 9-11 years old children.

One of the possible for this result can be, since all the previous studies were done with eye closed condition while present study was done with eye opened condition. This may be a cause of variation in the result compare to the previous studies. One more cause of these results can be the maturation of myelin sheath of different pathway of auditory system. Yakovlev et al. (1967) reported that completion of myelin sheath differs as myelin sheath of each nerve fibres starts developing in the different time. Myelin sheath of motor nerves get mature between 5 and 10 months of gestation period, whereas sensory nerves starts later and mature between 6 months of gestation period and 4 years of age. Myelination of vestibular nerves get completed by the 5 to 9 months of gestation period. However, the duration of maturation of brainstem reticular formation, which closely relates to the vestibular system, is 1 month to 10 years of age.

The pathway of the oVEMP involves the brainstem structures and hence the latency of oVEMP peaks may be more for 9-11 years old children compared to the 11-13 years old children and adults.

Amplitude measures of oVEMP

The ocular VEMP responses were recorded from both the ears of all the participants from all the groups. The amplitude of n1-p1 complex and p1-n2 complex were measured. Descriptive statistics was done to find out the mean and standard deviation for amplitude of n1-p1 complex and p1-n2 complex. The descriptive results of amplitude of both ears of all three groups are given in table 4.5.

Table 4.5

Mean and standard deviation of amplitude of n1-p1 complex and p1-n2 complex of all three groups of both ears.

Parameter		**Amplitude of n1-p1 complex**		**Amplitude of p1-n2 complex**	
		Mean	SD	Mean	SD
Group I	Left	5.44	2.68	4.79	2.82
	Right	4.84	3.12	5.00	3.26
Group II	Left	8.20	5.33	7.37	4.82
	Right	8.68	5.42	7.31	4.36
Group III	Left	5.67	3.90	5.05	3.48
	Right	5.08	3.21	4.32	2.52

It can be seen from the table-4.5 that mean amplitude of n1-p1 complex and p1-n2 complex is highest for group II children followed by group III than group I. To understand the overall significant main effect, Repeated measure ANOVA with groups and ears as between subject factors was done. Repeated measure ANOVA showed significant main effect for groups [$F (2, 84) = 3.82, 0.02, p < 0.05$], however, Repeated measure ANOVA failed to show any significant main effect for ears [$F (2, 84) =0.76, 0.25, p < 0.05$].Repeated measure ANOVA also failed to show any significant interaction between the groups and ears [$F (2, 84) = 1.58, 0.21, p < 0.05$]. Since, group showed significant main effect in repeated measure ANOVA, Duncan's Post Hoc was done to understand the group for the amplitude of n1-p1 complex and p1-n2 complex. Duncan's Post Hoc results are given in table 4.6.

Table: 4.6

Duncan's Post Hoc result to understand group differences for amplitude

Groups	Group I	Group II	Group III
Group I		**p< 0.05**	p > 0.05
Group II			**p< 0.05**

It can be seen from table-4.6 that only group II differed from group I and group III. Further there was no significant difference between group I and group III. Since, the ear did not show a significant main effect, data from the two ear were combined. The mean and S.D of the combined data were calculated in descriptive statistics and the result is shown in table 7.

Table 4.7

Mean and standard deviation of amplitude of oVEMP (combined from two ears)

Parameters	**Group I**		**Group II**		**Group III**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
n1-p1 amplitude (µV)	5.14	2.88	8.44	5.29	5.38	3.52
p1-n2amplitude (µV)	4.90	2.99	7.34	4.51	4.69	3.01

It can be seen from table-4.7 that mean amplitude of n1-p1 complex and p1-n2 complex is highest for group II children followed by group III than group I. The figure 4.3 illustrates the combined mean amplitude of n1-p1 complex and p1-n2 complex in all the three groups.

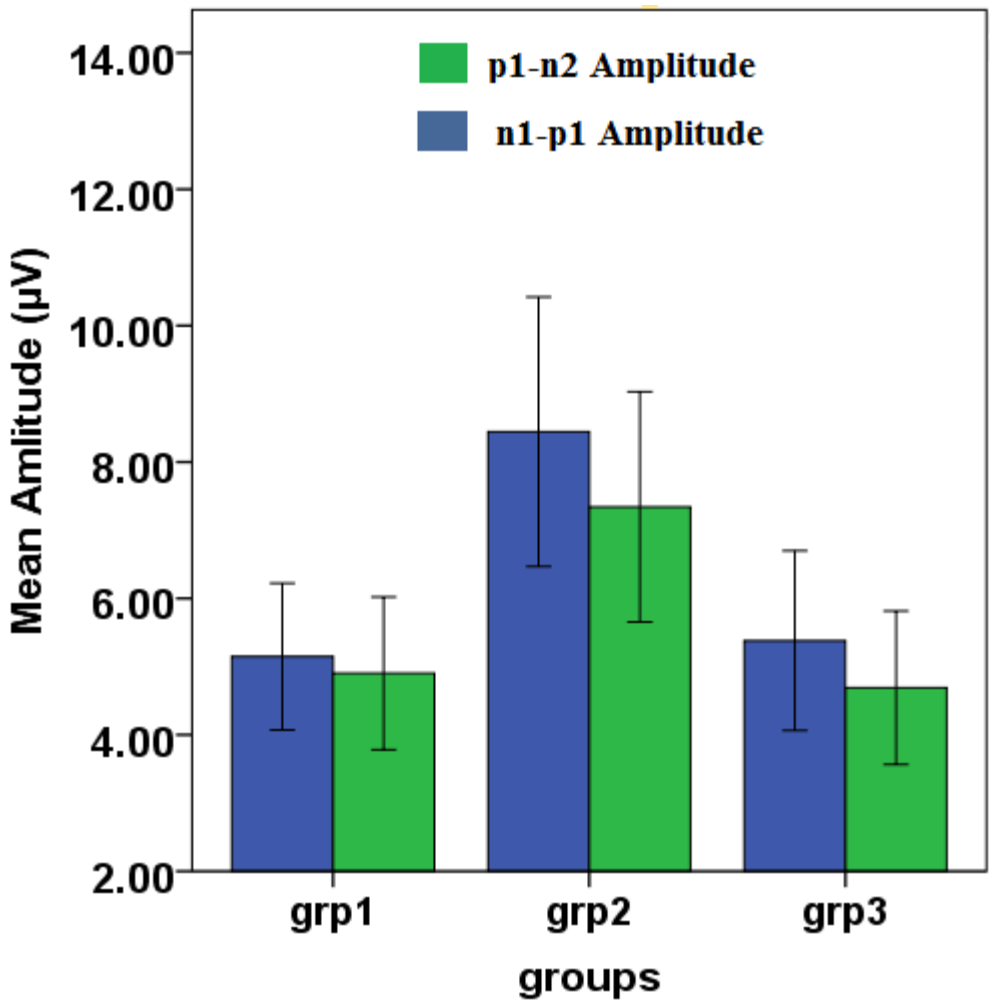


Figure 4.3. *Combined amplitude of n1-p1 complex and p1-n2 complex.*

MANOVA was done to see the group effect for amplitude of n1-p1 complex and p1-n2 complex. MANOVA showed significant main effect for amplitude of n1-p1 complex [$F(2, 87) = 6.25$, $p < 0.05$] and amplitude of p1-n2 complex [$F(2, 87) = 5.08$, $p < 0.05$]. Since, amplitude of n1-p1 complex and p1-n2 complex showed significant group effect in MANOVA, Duncan's Post Hoc was done to understand the groupwise differences for the amplitude. Duncan's Post Hoc results are given in table 4.8.

Table 4.8.

Duncan's Post Hoc results for groupwise differences for oVEMP amplitude

	n1-p1 amplitude (µV)		**n1-p1 amplitude (µV)**	
	Group I	Group II	Group I	Group II
Group I		**p < 0.05**		**p < 0.05**
Group III	p > 0.05	**p < 0.05**	p > 0.05	**p < 0.05**

Table 4.8 clearly shows the significant difference in amplitude of n1-p1 complex and p1-n2 complex between the group II and other two groups (group I and group III). Whereas, there is no significant difference seen in group I and group III.

To summarize the present study the oVEMP was recorded on the school going children (aged 9-11 years & 11-13 years) and adult (aged 25-40 years). Latency of n1, p1 and n2 peaks and the amplitude of n1-p1 complex and p1-n2 complex were recorded for comparison between the each group. The latency of each peaks of group I were significantly different from the group II and group III. However, there is no significant difference of latency between the group II and group III. Similarly, amplitude of n1-p1 complex and p1-n2 complex of group II were significantly different from the group I and group III. Whereas, there was no significant difference between the group I and group III.

Studies related to oVEMP in children have just started to appear. Hsu, Wang and Young (2009) recorded oVEMP in 3- 13 year old children 24-33 years old adults and they found no significant difference in latency of n1 or p1 or n2 peaks of oVEMP between children and adults. The authors concluded that the oVEMP is matured in children by 3 years of age.

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However, present study shows different results compared to the previous studies reported in the literature. In the present study, 9-11 years children had significant difference in latency of oVEMP compared to 11-13 years and 25-40 years age range. The latency of 9-11 years old children old was more compared to the 11-13 year old children and adults. This implies that the oVEMP is not matured in 9-11 years old children.

One of the possible for this result can be, since all the previous studies were done with eye closed condition while present study was done with eye opened condition. This may be a cause of variation in the result compare to the previous studies. One more cause of this results can be the maturation of myelin sheath of different pathway of auditory system. Yakovlev et al. (1967) reported that completion of myelin sheath differs as myelin sheath of each nerve fibres starts developing in the different time. Myelin sheath of motor nerves get mature between 5 and 10 months of gestation period, whereas sensory nerves starts later and mature between 6 months of gestation period and 4 years of age. Myelination of vestibular nerves get completed by the 5 to 9 months of gestation period. However, the duration of maturation of brainstem reticular formation, which closely relates to the vestibular system, is 1 month to 10 years of age.

The pathway of the oVEMP involves the brainstem structures and hence the latency of oVEMP peaks may be more for 9-11 years old children compared to the 11-13 years old children and adults.

Chapter-V

SUMMARY AND CONCLUSIONS

The vestibular system is one of the important system (among the three system- the propeoceptive system, the visual system and the vestibular system) for the balancing of the body during the walking and standing position. Dysfunction of the vestibular system can cause a major impact on the child's development. Vestibular system has different pathways – vestibulo-ocular, vestibulo-spinal and vestibulo-collic reflex. So, it is very important to assess all the different pathways of vestibular system. Ocular vestibular evoked myogenic potential (oVEMP) is one new type of vestibular evoked myogenic potential which mainly assesses the functioning of utricle and superior branch of the vestibular nerve (Jacobson et al., 2011).

In the present study, three groups of participants were included,

1. Group I: School going children of age 9-11 years.
2. Group II: School going children of age 11-13 years.
3. Group III: Adults of age 25-40 years.

All the participants of the study were normal and healthy. Pathological conditions were ruled out by series of audiological procedure: taking detail case history, otoscopic examination, immitance measurement, puretone audiometry and auditory brainstem responses (ABR).

oVEMPs were recorded for all the participants using 500 Hz tone burst stimuli presented at 125 dB SPL intensity with a rarefaction polarity. The non-inverting electrode was placed 1 cm below the eye, the inverting electrode was placed 1 cm below the non-inverting electrode. oVEMP was recorded in upper gaze and contralateral stimulation for all the participants of all the three groups.

Following parameters were noted for all the participants

- Latency of n1, p1 and n2 peaks of oVEMP for participants of all the three groups.
- Amplitude of n1-p1 complex and p1-n2 complex for the participants of all the three groups.

Statistics were done for analysis using the SPSS version 20 software. Following statistical analysis were done:

- Descriptive statistics was done to find out the mean and the standard deviation for latency of n1 peak, p1 peak and n2 peak for all the three groups.
- Descriptive statistics was done to find out the mean and the standard deviation for the amplitude of n1-p1 and p1-n2 complex for all the three groups.
- Repeated measure ANOVA was done to see the overall effect of groups and ear on latency of n1 peak, p1 peak and n2 peak.
- Duncan's post hoc test was done to see the group differences.
- Repeated measure ANOVA was done to see the overall effect of groups and ear on amplitude of n1-p1 peak and p1-n2 peak.
- Duncan's post hoc test was done to see the group differences.
- Multiple analysis of variance was done to see the overall group differences for latency of n1 peak, p1 peak and n2 peak and amplitude of n1-p1 peak and p1-n2 peak.
- Duncan's post hoc test was done to understand group wise differences for different peaks.

Results of the present study revealed the following:

- The latency of n1, p1 and n2 peaks of oVEMPs decreased as the age increased. Statistical analysis showed the significant difference between group I and other two groups (group II & group III). The latency of oVEMP peaks was more for group I as compared to the group II

and group III. Further there was no significant difference between group II and group III for the latency parameters.

- The mean amplitude of n1-p1 complex and p1-n2 complex showed the difference between the groups. Amplitude of oVEMP for Group II was significantly more as compared to the group I and group III. However, there was no significant difference in amplitude of n1-p1 peak and p1-n2 peaks between group I and group III.

Conclusions

oVEMP is a quick and non-invasive test for the assessment of utricle and superior vestibular nerve. Assessment of vestibular system is very much important for the development of balancing system in the children. Results of the present study revealed a significant difference in latency of oVEMP parameters between the different groups. Latency of group I was more as compared to group II and group III, which indicates a possible of maturation of otolith ocular pathways in children.

Implications of the study

- This study gives the diagnostic significance of oVEMP in the assessment of vestibular system in the children.
- This study provides data for latencies and amplitude of peaks of oVEMP in children. The data can be utilized for the comparison of oVEMPs' peak latencies and amplitudes with the clinical population.

Chapter- VI

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