THE EFFECT OF MODE OF EXCITATION OF STERNOCLEIDOMASTOID MUSCLE ON VESTIBULAR EVOKED MYOGENIC POTENTIALS

Register number: 06AUD018

A dissertation submitted in part fulfillment of
Final Year M.Sc. (Audiology),
University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING
NAIMISHAM CAMPUS, MANASAGANGOTHRI
MYSORE
April-2008

CERTIFICATE

This is to certify that this dissertation entitled ***"The Effect of Mode of Sternocleidomastoid (SCM) Excitation on Vestibular Evoked Myogenic Potentials (VEMP)"*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration No. 06AUD018. 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.

Mysore

April, 2008

Dr. Vijayalakshmi Basavaraj
Director
All India Institute of Speech and Hearing
Manasagangothri
Mysore-570 006.

CERTIFICATE

This is to certify that the dissertation entitled **"The Effect of Mode of excitation of Sternocleidomastoid Muscle on Vestibular Evoked Myogenic Potentials"** has been carried out 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.

GUIDE

Dr. Vijayalakshmi Basavaraj

Director

All India Institute of Speech and Hearing

Manasagangothri, Mysore-570006.

Mysore

April, 2008.

DECLARATION

I hereby declare that this dissertation entitled **"The Effect of Mode of excitation of Sternoceidomastoid Muscle on Vestibular evoked Myogenic Potentials"** is the result of my own study and has not been submitted earlier in any other University for the award of any other Diploma or Degree.

Mysore,

April, 2008. **Register No: 06AUD018**

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Chapter- I

Introduction

The Vestibular Evoked Myogenic Potential (VEMP) is an inhibitory potential recorded from the Sternocleidomastoid muscle (SCM) in response to loud sounds.

VEMPs are short latency Electromyograms (EMG) that are evoked by higher-level acoustic stimuli and are recorded from surface electrodes over the tonically contracted SCM muscle. The neurophysiologic and clinical data indicate that the VEMPs are mediated by a pathway that includes the saccular macula, inferior vestibular nerve, the lateral vestibular nucleus, the lateral vestibulospinal tract, and the motor neurons of the ipsilateral SCM muscle (Halmagyi & Curthoys, 2000).

VEMP testing is a new diagnostic tool for professionals who are dealing with assessment of Vestibular and Auditory disorders. VEMPs were first described by Bickford, Jacobson, and Cody (1964), and recently have been proposed as a reliable clinical test of saccular or inferior vestibular nerve function (Colebatch, 2001).

Typical tests, which are used since past in evaluation of vestibular disorders such as Electronystagmography (test battery) actually assess only semicircular canals and superior vestibular nerve but not the saccule and inferior vestibular nerve. Evidence from animal studies suggests that, VEMP is of saccular origin via the inferior vestibular nerve in response to loud sounds. Thus, by adding of VEMP testing into clinical routine of vestibular evaluation would provide complete and comprehensive assessment of vestibular apparatus including vestibular nerve.

Colebatch, Halmagyi, and Skuse (1994) established a reliable procedure to record the myogenic potentials evoked by clicks. These authors revised previous recording procedures by putting surface electrodes on the strenocleidomastoid (SCM) muscle, rather than placing them at the inion.

Normal VEMP responses are characterized by biphasic (positive–negative) waves. In a majority of studies, the peaks and troughs are usually labeled with the mean latency in milliseconds preceded by the lowercase letters "p" (for positive) or "n" (for negative), as proposed by Yoshie and Okudaira (1969) to distinguish them from neurally generated evoked potentials. The first positive–negative complex is often labeled as p13–n23 (Colebatch JG, Halmagyi GM, Skuse NF, 1994). Authors have also reported later serial peaks of VEMP labeled as n34 –p44. The VEMP amplitudes are large and vary from a few micro volts, depending on the muscle tension and the intensity of stimuli. (Cheng & Murofushi, 2001a, 2001b).

NEED FOR THE STUDY

The balance system is considered to be the more complex than the auditory system. Thus, evaluation and diagnosis of disorders related to this system are highly complex, leading to difficulty in management of patients with balance disorders. Because of the geometric proximity of the vestibular system to the auditory system, hearing and balance disorders often co-exist. Therefore, the audiologist is often called upon in the evaluation of both the vestibular and auditory systems. There are various tests that can be carried out in vestibular clinic, such as, Electronystagmography (ENG), Rotational chair test, tests for postural control Assessment that majorly focus on assessing vestibulo spinal pathways and VEMP test. Among all these tests, ENG is the most widely used test since long, ENG is not a single test but consists of various sub tests in its battery such as caloric test, Gaze test etc.,

All the tests mentioned above though address the issue of assessing the same problem i.e. vestibular disorder; each test has its own unique significance and hence cannot be replaced by other test. Thus, the information obtained from VEMP testing is different from the information obtained from the results of ENG tests. ENG assess the Semicircular canals, utricle and superior vestibular nerve where as VEMP assess saccule and inferior vestibular nerve.

Hence, VEMP testing for normal saccular function, when combined with the right battery of tests, can provide valuable diagnostic information about conditions such as Meniere's disease, Vestibular labyrinthitis, Benign paroxysmal positional vertigo, Superior canal dehiscence, Tullio phenomenon, Multiple sclerosis, Spinocerebellar degeneration, Acoustic neuroma. Conditions like Meniere's disease, neuroma and multiple sclerosis have a high incidence of absent potentials; conditions like vertigo and dehiscence show lower threshold values. Conditions such as acoustic neuroma and multiple sclerosis show some latency shifts.

VEMP testing is considered to be easy, but there are a lot of technical pitfalls such as, operator pitfalls, assuring neck muscle activation, electrical artifact, mode of neck muscle activation, sound stimulus, electrode layout etc.,

There have been lots of studies done on VEMP to investigate effect of stimulus parameters such as, intensity, frequency, Rise/Fall time, Plateau time, effect of Recording methods such as electrode placement, air conduction vs bone conduction, and effect of subject variables such as, age related changes, pathology (Tullio phenomenon, Meniere's disease, neuroma, dizziness, vertigo etc.,) Researches in India have dealt with investigating the effect of age, intensity of stimulus and dizziness on VEMP response (Kaushal, 2006). Research in India has also focused on studies of the later peaks (n34 &p44) of VEMP (Deepashree, 2007).

Research in the area of VEMP have addressed the issues of subject variables and test parameters, but literature does not provide any suggestion to the clinicians about which method/mode of excitation of sternocleidomastoid muscle should be employed. Since, as mentioned in literature there are several modes of excitation of SCM muscle.

So, as patient comfort and reliability of mode of excitation of sternocliedo mastoid are also the factors to be considered while testing, there is a need to study the mode of excitation of SCM muscle which is more comfortable to the patient and is also more reliable.

Keeping all this in mind the study was taken up with the following aim

Aim of the study

- To explore the mode of exciting sternocleidomastoid muscle for VEMP testing that gives better amplitude, is reliable and yields maximum patient comfort

Objective of the study

- To compare the different modes of exciting sternocliedo mastoid muscle for VEMP testing in terms of: response rate, wave morphology, latency – amplitude measures and client comfort.

Research design

The research design used to prove the following Hypothesis was ***"within subject design"***

Hypothesis

There is no significant difference between the three modes of excitation of sternocleidomastoid muscle in terms of latency, amplitude, response rate, wave morphology of VEMP and client comfort.

Chapter-II

Review of Literature

Complete assessment of the vestibular function is a part of the assessment carried out in any department of otolaryngology and audiology. The test that is being used in the vestibular evaluation since long is Electronystagmography (ENG), which comprises of a vestibular test battery. But, ENG assess only the function of lateral semicircular canal and superior vestibular nerve and not the other parts of vestibular apparatus in humans such as saccule and inferior vestibular nerve. During the past few years this lacuna in vestibular evaluation is filled by a test namely Vestibular Evoked Myogenic Potential (VEMP).

Vestibular evoked myogenic potentials (VEMP) are responses from the otolithic organs i.e. the saccule and the utricle to the high intensity acoustic stimulation. These responses can be acquired from the anterior neck muscles, specifically from the Sternocleidomastoid (SCM) muscles. There is initially biphasic positive-negative response (p13-n23) recorded from the averaged EMG which occurs at short latency and ipsilateral to the stimulated ear (Colebatch, Halmagyi & Skuse, 1994).

VEMP has been used as a clinical tool, which provides additional information about disturbances of vestibular function as a result of their dependence upon different vestibular receptors.

1. Neck muscles via the medial vestibulospinal tract (MVST).
2. The leg muscles via the lateral vestibulospinal tract (LVST). (Colebatch & Halmagyi 1994; Wilson & Boyle, 1995; Murofushi, Halmagyi, Yavor, & Colebatch, 1996; Uchino & Sato, 1997; Kushiro & Zakir, 2000).

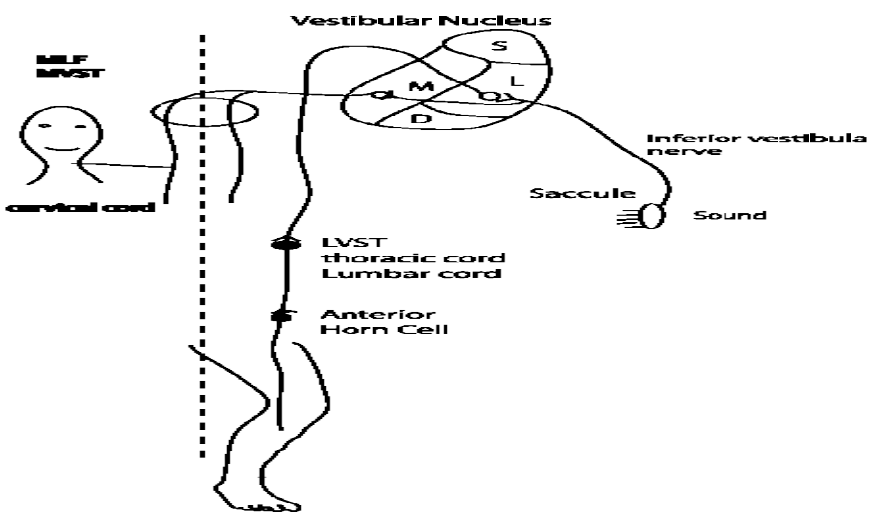


Figure 1. Pathway of Vestibular Evoked Myogenic Potential.

Anatomy and Physiology of VEMP

The Saccule (a receptor of linear acceleration in mammals) which is similar in anatomy to utricle is connected to the cochlea via the cochlear duct (ductus reunions). In general, the semicircular canals are involved in dynamic functional response, i.e. detection and coding of rotation movements of the body in space and coordinating reflexive control of eye movements. In contrast the utricle and saccule respond to static forces i.e. maintaining posture and absolute position in space. In humans and most vertebrates, the saccule remains sensitive to acoustic stimulation even though it is involved only in vestibular function and not hearing.

Output from the peripheral vestibular structures is conveyed to the central nervous system via the vestibular nerves. Animal (cat) investigations show that fibers within the vestibular nerve activated by acoustic stimulation of the saccule have spontaneous discharge rates within the range of 200 to 1000 Hz (McCue and Guinan 1996, Todd, Cody and Banks 2000).

- Stimulation of the saccule generates inhibitory postsynaptic potentials in motor neurons of the neck muscle (Todd cody and Banks 2000 Uchino et al 1997). Following the presentation of high intensity sound, there is temporary reduction in muscle activity, recorded as the positive wave in the VEMP.
- Cell bodies for vestibular nerve fibers are in the vestibular ganglion (Scarpa's ganglion). Myelinated bipolar nerve cells extend from the innervations of the vestibular hair cells at their distal end to the termination of axons in the brainstem (the proximal end).
- There are superior and inferior components or divisions within the vestibular ganglion. With respect to VEMP anatomy, the superior division innervates the anterior portion of the macula within the saccule, whereas the

inferior division innervates the posterior portion. Although the saccule is served by both the superior and inferior vestibular nerves, clinical findings in patients with various pathologies provide evidence that the VEMP is dependent on the integrity of the inferior vestibular portion of the auditory nerve. In mammals fibers from the saccule, along with some from the semicircular canals and utricle, enter the inferior vestibular nucleus.

From the inferior vestibular nucleus the pathways underlying the VEMP traverse downward, primarily along the lateral vestibulospinal tract to the motor neurons within the eleventh (accessory) cranial nerve that innervate selected muscles in the neck (e.g. Todd, Cody and Banks 2000).

Vestibulospinal tracts descend within the brainstem, including the medulla and the cervical region of the spinal cord. Along the descending pathway, fibers from the vestibulospinal tract connect with neurons in the motor nucleus of cranial nerve XI (the accessory nerve). The SCM muscle is innervated mostly by the accessory cranial nerve (Fitzegerald, Comerford and Tuffrey 1982). From the motor nucleus of cranial nerve XI, nerve fibers take a rather indirect route from the medulla, through a cranial opening (jugular foramen) and then to neck muscles (SCM and trapezius muscles).

The VEMP is commonly recorded from an electrode placed on the strenocleidomastoid (SCM). However sound evoked myogenic potentials or changes in muscle tension, referred to sometimes as the “inion response” and also reflecting vestibular system function, can be detected from the posterior extensor neck muscles, including the trapezius muscle and the splenius capitis muscle as shown in figure-2 (e.g. Ferber- Viart, C., Dubreuil, C., & Duclaux, R. (1998); Sakakura, K., Miyashita, M., Chikamatsu., K. (2005); Wu, Young, and Murofushi 1999). The path ways involved in stimulating and recording the VEMP are ipsilateral (e.g. Halmagyi and Curthoys, 1999). Masking sound presented at relatively high levels (>75 dB HL) to the nonstimulus ear, however, may result in attenuation of VEMP amplitude (e.g. Takegoshi and Murofushi 2003) perhaps due to stapedius muscle contraction bilaterally

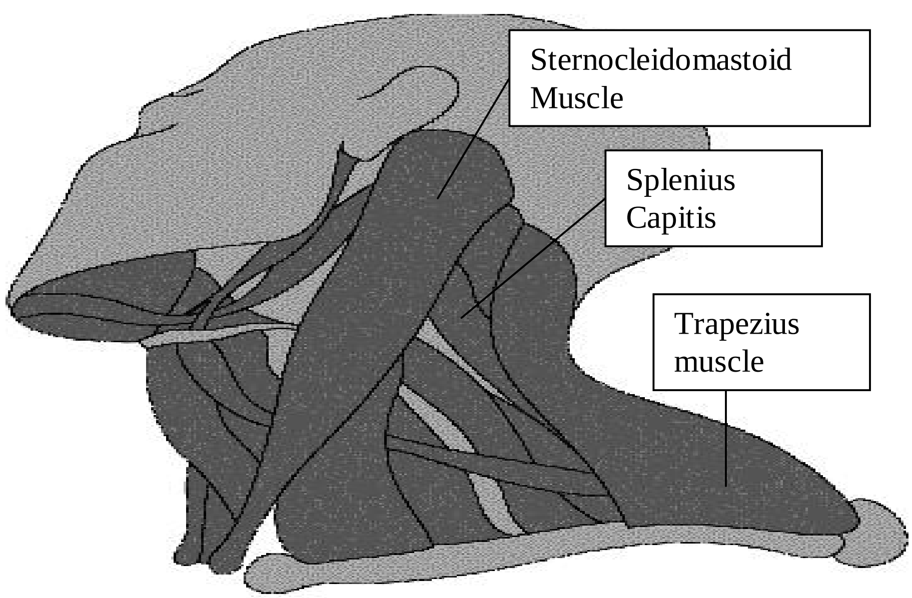


Figure:2 Daigram of Posterior neck muscles

Methods for recording VEMP

VEMPs evoked by bone- conducted stimuli

A bone- conducted tone burst delivered over the mastoid process via a B71 clinical vibrator (radio ear corporation, Philadelphia, PA), routinely used in audiometric testing, evokes VEMPs despite conductive hearing losses. VEMPs are often bilateral as the stimulus is transmitted via bone and activate end organs on both sides. The ipsilateral VEMP is about 1.5 times larger and occurs approximately 1 millisecond earlier. Rarely larger responses have been recorded contra lateral to the stimulated ear (Sheykholeslami, Murofushi, Kermany, & Kaga, 2001; Welgampola. Rosengren, Halmagyi, & Colebatch, 2003).

VEMPs evoked by galvanic simulation

A short duration (2 millisecond) pulsed current delivered via electrodes attached to the mastoid processes evokes a p13-n23 response on the side ipsilateral to cathodal stimulation. Similar to that evoked by sound stimuli of 4mA/2msec as used for clinical testing are well tolerated by patients. Such a current in close proximately to the recording site causes a large stimulus artifact and specific subtraction techniques are required to recover the response of interest (Watson & Colebatch 1998).

VEMPs Evoked by air conduction stimulus

Type of stimulus

The sound stimulus of click or short tone burst can be used to induce VEMP response (Huei-Jun Wu., An-Suey Shiao., Yih-Liang Yang., Guo-She Lee. 2007). Welgampola.MS, Colebatch.JG (2001) concluded that tone burst evoked myogenic responses are similar to click evoked myogenic responses and require lower absolute stimulus intensities than that of clicks.

Huei-Jun Wu., An-Suey Shiao., Yih-Liang Yang., Guo-She Lee. (2007), have compared the VEMP responses evoked by short tone burst with those evoked by click stimuli in healthy young individuals. Results indicated that short tone burst stimuli (500Hz) evoked prolonged latencies and greater amplitudes of VEMP response over click stimuli. Authors suggested to use short tone burst stimuli because the latencies and amplitudes of click stimuli were significantly different among several labs.

Akin, F. M., Murnane, O. D., & Proffitt, T. M. (2003), have studied the effect of frequency on tone burst evoked VEMPs and found 500Hz to be the frequency of tone Burst eliciting larger VEMP amplitude and lower thresholds.

Monaural Vs Binaural presentation

Wang and Yung (2003) investigated VEMP with binaural and monaural acoustic stimuli and found that binaural VEMPs can produce information equivalent to monaural VEMPs in terms of response rate, latencies, and Interaural Amplitude Difference (IAD) ratio in healthy subjects as well as in subjects with Meniere's disease.

Stimulus Repetition rate

Wu and Murofushi, (1999) attempted to study the influence of stimulus (click) repetition rate on VEMP response. Results of study revealed that VEMP generated at lower repetition rates, seemed to be more marked and constant. Also reported that with regard to patient compliance and examination time, a 5Hz RR is advisable compared to 1Hz, 10Hz, 15Hz and 20Hz if both short examination time and high signal to noise ratio are required.

Stimulus Duration

Haung, T. W., Su, H. C., & Cheng, P. W. (2005), studied the VEMP response evoked by various click durations (0.1 to 0.5ms) and found that 0.5ms duration of click elicits more prominent wave morphology, shorter interaural latency than any other duration. And suggested that 0.5ms is superior to other click durations in eliciting VEMP response for clinical use.

Stimulus level

Akin, F. M., Murnane, O. D., & Proffitt, T. M. (2003), have studied the effect of intensity level on VEMP response and have seen that response amplitude of the VEMP increased with click and tone-burst level, where as VEMP latency was not influenced by the stimulus level.

Subject related factor

Effect of age

Su, Haung, Young, and Cheng (2004), investigated the effect of age on VEMPs. In their study, Group I included patients aged<20years, Group II subjects age ranged from 21 to 40 years, Group III subjects were 41 to 60 years and group IV included subjects older than 60 years. Results showed that VEMP response rate from groups I to IV was 98%, 96%, 90%, and 60% respectively, with a significant difference only between group IV and other groups. Although the p13 latency had a trend to prolong as age increased, no significant correlation was noticed with age. Hence as age increased over 60 years, the VEMP response rate and amplitude decreased dramatically, and n23 latency prolonged. These findings suggest that aging could deteriorate the saccular and corresponding neural functions.

Effect of muscle tension

Colebatch, J. C., Halmagyi, G. M., & Skuse, N. F. (1994), monitored electromyography (EMG) activity with an oscilloscope and quantified the activity with mathematical analysis. In all their participants, there was a linear relationship between the amplitude of the response and the mean level of EMG activity. This finding was confirmed by later studies and is considered as one of the unique features of VEMPs.

Many procedures have been used to activate the neck muscle. Bickford, R. G., Jacobson, J. L., & Cody, D. T. R. (1964), applied different loads to a plastic loop and pulley that changed the traction of neck muscle. Colebatch, J. C., Halmagyi, G. M., & Skuse, N. F. (1994), asked their participants to press against a padded bar to activate SCM muscles. In studies by Welgampola and Colebatch (2001) and Robertson and Ireland (1995) participants were placed in a supine position and asked to elevate their body to activate the SCM muscles on both sides simultaneously. Ochi, K., Ohashi, T., & Nishino, H. (2001) & Toddy, N. P. M., Cody, F. W. J., & Banks, J. R. (2000), used a sitting position and instructed participants to turn their body away from the stimulated ear.

Although different procedures have been used to activate the neck muscles, the published studies provide consistent findings that the muscle tension not the body position itself, influences the presence and the amplitude of the response (Colebatch, J. C., Halmagyi, G. M., & Skuse, N. F. (1994), Ochi, K., Ohashi, T., & Nishino, H, 2001).

VEMP in Clinical Use

Superior canal dehiscence

Sven-Olrik., Cremer, P. D., Carey, J. P., Weg, N., & Minor, L. B. (2001), have studied VEMP responses in subjects with Superior Canal Dehiscence and found lowered VEMP thresholds in these subjects and concluded that VEMP can be included in the test battery along with symptoms, signs and CT imaging in diagnosis of Superior Canal Dehiscence syndrome. Krister Brantberg (1999) also found low threshold for VEMP responses especially in the frequency range of 0.5 – 1 KHz in 3 patients with Superior Canal Dehiscence. Zhou.G, Gopen.Q, Poe.D.S (2007) Vestibular evoked myogenic potential is highly sensitive and specific for Superior Canal Dehiscence, possibly better than CT scan.

Vestibular neuritis

Halmagyi and Colebatch, (1995) reported in their study that patients who did not have caloric responses on the affected sides indicated dysfunction of the lateral semicircular canal. Results showed VEMPs were normal in 6 patients, reduced in 5 patients and absent in 11 patients. Therefore, results not only suggested that VEMPs were not of lateral canal origin but also revealed different pathologies involved in vestibular neuritis. Absence of VEMP is reported in patients with Vestibular Neuro labyrynthitis indicating involvement of inferior vestibular nerve (Murofushi., Halmagyi., Yavor., & Colebatch. 1996).

Halmagyi, G. M., Aw, S. T., Karlberg, M., Curthoys, I.S., & Todd, M. J. (2002), reported 2 patients with acute vertigo but normal lateral semicircular canal function as indicated by the caloric test. It was reported that these 2 patients had selective inferior vestibular neuritis since VEMPs were absent on the affected side for both cases.

Although the recovery of superior vestibular nerve functions has been reported, there is little information about the recovery of inferior vestibular nerve functions in patients with vestibular Neuritis. A study was done to verify the recovery of inferior vestibular nerve using VEMP testing and found that 13 patients with vestibular neuritis who showed absence of VEMP in the initial examination when tested after recovery showed VEMP responses. The authors report that it takes 6months to 2 years for recovery to the normal range of VEMP measures. (Murofushi.T, Iwasaki.S, Ushio.M, 2006).

Vestibular Schwannoma/Acoustic Neuroma

The Auditory brainstem response test and the caloric test have been used in addition to magnetic resonance imaging in the diagnosis of acoustic neuroma. Caloric test and the auditory brainstem response test mainly reflect functions of the cochlear nerve and superior vestibular nerve respectively. To know the tumor involvement into the inferior vestibular nerve, caloric responses and VEMP responses were reviewed and compared between 21patients with acoustic neuroma, confirmed surgically and 8 normal subjects. Abnormal VEMP and Caloric responses were found in 17 out of 21 patients, 3 patients had abnormal VEMP although there was a normal caloric response and 3 patients had abnormal caloric responses although there were normal VEMP responses. These findings suggest that VEMP could be useful in diagnosing acoustic neuroma, especially for

Classifying acoustic neuromas according to the involved (Vestibular & auditory) nerves. (Murofushi, Matsuzaki, and mizuno, 1998).

Diallo, B.K, (2006), stated that VEMP can be included in the audio vestibular assessment in diagnosing all sizes of vestibular schwannomas. It was also reported that inter aural latency of VEMP can be a tool to diagnose vestibular schwannomas, (Yang, W., Han, D., Wu, Z., Zhang, S., Ji, F., Zhou, N., & Gou, W, 2005). Itoh, A., (2001), concluded that VEMP test compromises a useful new diagnostic method for identifying lower Brainstem lesions in which ABR is present and VEMP is absent. VEMP is useful for detecting dysfunction of inferior vestibular nerve in patients with acoustic neuroma and can provide useful information in diagnosing acoustic tumors. (Matsuzaki, M., Murofushi, T., & Mizuno, M. 1999; Takechi, N., (2001).

VEMP results were not always correlated with the nerve where the tumor was located. Moreover no correlation was found between the VEMPs and tumor size (Tsutsumi, Tsunoda, Noguchi, & Komatsuzuki, 2000).

Meniere's disease (Endolymphatic hydrops):

Robertson and Ireland (1995) reported that VEMPs were absent in all 3 of their patients with Meniere's disease (MD). VEMPs in patients with MD showed that 54% of the patients had no VEMPs when clicks were used as stimuli (De waele, C., Hay, P. T., Diard, J. P., Freyss, X., & Vidal, P. P, 1999. Shojaku, H., Takemori, S., Kobayashi, K., Watanabe, Y. (2001), reported similar results in which 8 out of 15 patients with MD had abnormal VEMP amplitude.

Ohki, M., Matsuzaki, M., Sugasawa, K., & Murofushi, T. (2002), reported a very interesting finding i.e. absence of or abnormal VEMPs in contra lateral ears that may have delayed enadolymphatic hydrops.

VEMPs were altered in 35% of the affected ears and in 25% of the asymptomatic ears. The alterations were absence of responses in 7 cases, and increase in interaural amplitude difference ratios in one case. From this study concluded that VEMPs could present abnormalities in the affected and asymptomatic ears in patients with unilaterally defined Meniere's disease (Ribeiro, S., Almeida, R. R., Caovilla, H. H., & Gananca, M. M. 2005).

Seo, Node, Yukimasa, and Sakagami (2003) investigated to see whether endolymphatic hydrops in Meniere's disease could be diagnosed comparing VEMP before and after furosemide administration (F-VEMP). Results showed positive findings in all the three subjects with furosemide administration. So F-VEMP test may be useful in the diagnosis of endolymphatic hydrops.

Murofushi, Matsuzuki, and Takegoshi (2001) had taken 6 normal volunteers and 17 patients with unilateral Meniere's disease. VEMPs were recorded before and after administration of glycerol (1.3 g/kg body weight). He concluded VEMPs in some patients with unilateral Meniere's disease were improved by oral administration of glycerol. This result suggests that abnormal VEMPs in patients with unilateral Meniere's disease could result from endolymphatic hydrops.

Interaural amplitude difference (IAD) ratio of VEMPs correlates with the stage of Meniere's disease and can be used as another aid to assess the stage of Meniere's disease. (Young, Huang, and Cheng, 2003)

Murofushi, Shimizu, Takegoshi, and Cheng (2001) studied 134 patients (61 men and 73 women aged 0-75 years), of whom, 43 patients were with Meniere's disease, 62 with acoustic neuroma, 23 with vestibular neuritis and 6 with multiple sclerosis along wih18 healthy volunteers (13 men & 5 women aged 25-38 years). Results showed VEMPs were absent or decreased in 51% of patients with Meniere's disease (n=22); 39 with vestibular neuritis (n = 9), 77% with acoustic neuroma (n=28), and 25 % with multiple sclerosis (3 of 12 sides of 6 patients). They concluded that prolonged latencies of VEMP suggest lesions in the retro labyrinthine especially in the vestibulo spinal tract.

There are other applications of VEMP as well. VEMP testing is reported to be a promising method for diagnosing and following patients with Benign Paroxysmal Positional Vertigo and Meniere's disease, (Akkuzu, G., Akkuzu, B., Ozluoglu, L.N, 2006). Significant changes in VEMP wave were seen after the glycerol loading in terms of amplitude, but not in latency with Meniere's disease patients (Ban, J. H., 2007). VEMP has been recommended as a useful detector of asymptotic saccular hydrops and as a predictor of evolving bilateral Meniere's disease (Lin, M. Y., 2006).

Multiple sclerosis

The latencies of a vestibulo spinal reflex can be prolonged in multiple sclerosis (MS). The VEMP delay could be attributed to demyelination either of primary afferent axons at the root entry zone or secondary vestibulo spinal tract axons rather than to lesion involving vestibular nucleus. Measurement of VEMPs could be helpful in detecting sub clinical vestibulospinal lesions in suspected multiple sclerosis (Shimizu, Murofushi, & Sakurai, 2000).

Conductive hearing loss

Interference of sound transmission due to some disorders such as chronic otitis media (COM) may lead to absent VEMPs (Young, Wu & Wu 2002). Tone stimuli rarely elicit VEMP responses in patients with conductive hearing loss (Halmagyi, Colebatch, & Curthoys, 1994).

Yang and young (2003) had compared the tone burst and tapping evocation of myogenic potentials in patients with chronic otitis media have taken 22 ears with conductive hearing loss due to chronic otitis media. Results showed that 13 (59%) of the 22 ears showed positive VEMPs using the tone burst method whereas 20 ears (91%) displayed positive VEMPs by the tapping method. So they concluded that while stimulating, sound is attenuated by middle ear pathology, VEMPs are expected to be poorly elicited under such conditions. Myogenic potentials may be evoked with the tapping method to elicit the absent VEMPs that result from middle ear or inner ear pathology.

Bath, Harris, Ewan, and Yardley (1999) found click evoked, restores present in less than 10% of their group of patients with conductive hearing loss, compared with 97% of those without conductive hearing loss. As conduction across the middle ears ossicular chain is defective, VEMPs are attenuated or absent in subjects with Otosclerosis (Halmagyi, Cloebatch, and Curthoys, 1994).

Gentamycin therapy

DeWaele, Meguenni, and Freyss (2002) found that the VEMPs can be used to monitor the effects of low close intra tympanic gentamycin injections used to achieve chemical labyrinthectomy, a procedure used to control debilitating vertigo in Meniere's disease and other peripheral vestibulopathies.

Auditory Neuropathy

Sheykholeslami, Kaga, Murofushi, and Hughes (2000) studied 3 auditory neuropathy patients. These patients also complained of balance disorders. Tests of battery were administered, audiometric tests (pure-tone audiometry and speech discrimination tests), Otoacoustic emissions, auditory-evoked brainstem responses and vestibular function tests (clinical tests of balance, electronystagmography, damped rotation tests and VEMPs). VEMP responses were absent in the affected ear. They concluded that, in patients with isolated auditory neuropathy, the vestibular branch of the 8^{th} cranial nerve and its innervated structures may also be affected.

Sheykholeslami, Schmerber, Kermeny, and Kaga (2005) had recorded VEMP using tone burst in a case with bilateral auditory neuropathy (AN). There were no response on left ear stimulation and a biphasic response with normal latency and amplitude on right-ear stimulation.

Kaushalendra., sujith., Neeraj., Animesh, B. (2007), studied VEMP in subjects with auditory neuropathy to determine the involvement and incidence of vestibular dysfunction in cases with auditory neuropathy. It was evident in the results that 16 out of 20 ears showed absent or prolonged latency and reduced amplitude of VEMP responses. Authors have concluded that auditory neuropathy can affect the vestibular branch of the VIII cranial nerve.

Reviewing the literature available on VEMP testing shows that a majority of the factors affecting the stimulus and response or parameters have been studied and reported. However, there is scanty literature on the variable of the subjects comfort with respect to the various body positions or postures used to excite the strenocleidomastoid muscle. Hence, present study aimed at fulfilling the above mentioned lacuna in literature related to VEMP testing.

Chapter-III

METHOD

The present study aimed at investigating the effect of various modes of excitation of sternocleidomastoid muscle on vestibular evoked myogenic potentials.

Subjects

50 subjects in the age range of 18 to 25 years were selected for the study. This group consisted of 25 male and 25 female subjects. These were selected on the criteria that subject should be

- having bilateral hearing sensitivity within normal limits PTA<20dBHL
- having no history of conductive hearing loss
- having no history of tinnitus and vertigo
- having no history of neuromuscular problems in body & neck region
- having no history of intake of drugs that may lead to vestibulotoxicity

All the subjects underwent case history and basic hearing evaluation for the purpose of meeting subject selection criteria which included pure tone audiometry and impedance audiometry.

Instrumentation

- Calibrated diagnostic audiometer (GSI-61) with TDH-49 supra aural body phone with MX41AR cushions was used for Air conduction testing and B-71 Radio ear bone vibrator for bone conduction testing was used for pure tone audiometry.

- Calibrated Middle ear analyzer (GSI-Tympstar) was used for immittance measurements.

- I.H.S Smart EP (3.94 USBez) system with ER-3A Insert ear phone was used for testing vestibular evoked myogenic potentials.

Test Environment

All the tests were conducted in acoustically treated room with permissible noise levels as per ANSI S 3.1 (1991) standards.

Procedure

For all the subjects, case history was collected to rule out past history of conductive hearing loss, tinnitus, vertigo, neuromuscular problems in body & neck region and intake of drugs that may lead to vestibulotoxicity.

Pure tone thresholds were obtained using modified Hughson - Westlake procedure (carhart & Jerger, 1959), across octave frequencies (including interoctave frequencies) from 250Hz to 8KHz for air conduction stimuli and from 250Hz to 4KHz for bone conduction stimuli. Tympanometry was done to rule out middle ear pathology. 226Hz was the probe frequency at the intensity level of 85dBSPL.

All the Subjects selected based on the inclusion criteria were subjected to VEMP testing in left ear using three different modes of excitation of sternocleidomastoid muscle. Instructions were given to subjects regarding the following body postures required in testing:

A) Subject's body rotated to one side for measurement of VEMP on the opposite side in sitting position

B) Subject's body rotated to one side for measurement of VEMP on the opposite side while lying in supine position

C) Instructing the subject to press the Forehead against a soft surface

VEMP Testing

- As mentioned in the test protocol, VEMPs were recorded for all the subjects by an averaging of the acoustically evoked electromyogram of the sternocleidomastoid muscle. The site of electrode placement was prepared with skin preparation gel. Silver chloride disc electrodes were used with a conducting gel. Absolute electrode impedances were less than 5kohms and inter-electrode impedances were less than 2Kohms.

- Subjects were instructed about the three body positions and were asked to maintain the same during the test run. While testing VEMP for each subject in all the three positions subjects the tonic EMG level was maintained between 30 – 50 micro volts. A visual feed back was provided to the subject so as to monitor tonic EMG level of sternocleidomastoid muscle.

- A single-channel recording of the evoked potential was obtained with a non-inverting electrode placed at the mid point of sternocleidomastoid muscle, inverting electrode placed on the sternoclavicular junction, and the ground electrode on the forehead.

- VEMPs were obtained from each subjected evoked by 500Hz tone bursts (rarefaction onset phase, blackman gating function, two cycle rise-fall time with no plateau) presented at 95dBpeSPL. The stimuli were presented monaurally to the ear ipsilateral to the activated (excited) sternocleidomastoid muscle via ER3A (Etymotic Research) insert earphones at a rate of 3.1Hz.

- Each run of VEMP test consisted of 75 to 250 no. of sweeps, each run lasting for 45sec to 1min of duration. Minimum of required rest period was given to the subject between each run. VEMP test was done in all the three positions and a rest period was given after testing in each position

- Replicability of VEMP wave form was checked by performing VEMP on all clients in all modes by testing at least twice. It was also ensured that VEMP is absent at low intensity level i.e. 65dBpeSPL by testing all subjects in all the three positions at that level. This indirectly confirmed that the VEMP wave form present at higher intensity levels were indeed reliable.

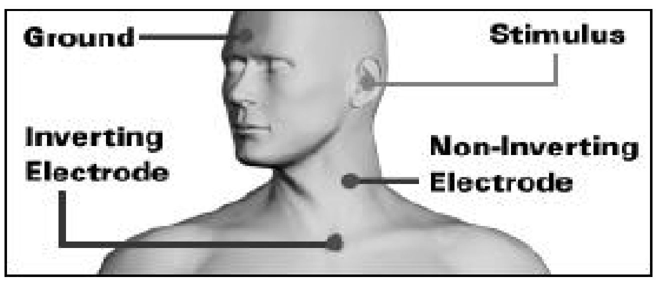
Test protocol for VEMP Testing

Table -1Shows the stimulus parameters

Transducer	Insert ear phones
Type	Tone burst
Frequency	500Hz
Duration	2-0-2 cycle Tone burst
Intensity	95dBpeSPL
Polarity	Rarefaction
Repetition Rate	3.1/sec Tone burst

Table 1. Stimulus parameters for VEMP test

Fig- 3 Shows the electrode configuration required for VEMP testing



Inverting (-) electrode	Sternoclavicular junction
Non-inverting (+) electrode	Midpoint of Sternocleidomastoid muscle
Ground electrode	Forehead
Stimulator	Side being tested

Fig 3. Electrode configuration required for VEMP test

Analysis time	

Pre stimulus	10 to 20ms
Post stimulus	50 to 100ms
Filter Settings	
High pass	1 to 30Hz
Low pass	250 to 1500Hz
Notch	None
Amplification	5000
Sweeps	75 to 250

Table -2 shows the acquisition parameters

Table 2. Acquisition parameters for VEMP test

After VEMP testing each subject was evaluated for patient comfort during VEMP testing in all modes of SCM muscle excitation using 3 point rating scale. The subjects were asked to rate their level of comfort in all positions based on rating scale.

<u>3 point rating scale was used to measure comfort</u>

1 – Intolerable

2 – Tolerable

3 – Comfort

Latency of p13 and n23 peaks was measured for all the subjects in all the three different body positions. Peak to trough (p13-n23) amplitude was also measured for all the waveforms in all the three positions. Response rate of VEMP was noted in all the subjects for all the positions. Wave morphology of all the wave forms was rated on a 3 point rating scale as good, average or poor by two audiologists independently by analyzing the morphology of wave forms.

The following data were generated separately for Males (N=25) and Females (N=25) for analysis;

1) Latency of p13, n23 and p13-n23amplitude in all the three positions

2) Response rate of VEMP in all the three positions

3) Ratings for wave morphology of VEMP response in all the three positions

4) Ratings for comfort by subjects in all the three positions

Chapter-IV

Results and Discussion

The present study aimed at investigating the effect of different body positions on the following parameters of VEMP assessment.

1) Latency of p13
2) Latency of n13
3) Amplitude p13-n23
4) Wave Morphology
5) Response rate
6) Comfort of the patient

The data was subjected to statistical analysis using SPSS software (version.15.0) to test the hypothesis of the study namely: there is no effect of mode of excitation of SCM on VEMP response. The statistical analysis included descriptive statistics, repeated measure analysis of variance and independent samples t-test.

1) The effect of body position on Latency of P13

Repeated measure analysis of variance was carried out to investigate the relationship of body position on latency of p13 peak in VEMP response. Table-3 shows the descriptive statistics of latency of p13 of males and females for the three body positions namely

A) Subject's body rotated to one side for measurement of VEMP on the opposite side in sitting position

B) Subject's body rotated to one side for measurement of VEMP on the opposite side while lying in supine position

C) Instructing the subject to press the forehead against a soft surface

Body position	Males		Females	
	Mean	S.D	Mean	S.D
A	14.1273	2.17566	13.7905	.85901
B	13.6400	2.32750	13.4800	1.09237
C	13.9053	2.44892	13.4111	.55507

Table 3. Mean & S.D of latencies of p13 (in msec) in male and female subjects

Results revealed that there is no significant difference in p13 latency between any of the three body positions used in VEMP testing for both male[$F(2, 30) = 1.295$, $p > 0.05$] as well as female [$F(2, 32) = 1.462$, $p > 0.05$] subjects at 0.05 level of significance.

The mean and S.D values of p13 latency of VEMP response in present study are almost in agreement with the studies on VEMP by various authors such as Cheng & Murofushi (2001), Akin et al. (2003), Kaushal (2006), and Huei-Jun et al. (2007).

The present study indicates that there is no significant difference in latency of p13 peak in VEMP response between the three body positions used. **Thus the null hypothesis that there is no effect of body position on VEMP measurement with respect to p13 latency is accepted.**

2) The effect of body position on Latency of n23

Repeated measure analysis of variance was carried out to investigate the effect of body position on latency of n23 in VEMP response. Table-4 shows the descriptive statistics of latency of n23 of males and females across the three body positions (A, B & C).

Body position	Males		Females	
	Mean	S.D	Mean	S.D
A	21.7255	2.39769	21.3048	1.75911
B	21.4310	2.49932	20.6100	1.50714
C	19.7368	2.35613	21.8444	1.46256

Table 4. Mean & S.D of latencies of n23 (in msec) in male and female subjects

Results revealed that there is significant difference in latency of n23 between position A and position C in males [$F(2, 30) = 4.415$, $p < 0.05$] and between position B and position C in female [$F(2, 32) = 4.881$, $p < 0.05$] subjects at 0.05 level of significance. In males C position yielded shorter latency of n23 than A position and in females B position yielded shorter latency of n23 than C position. **Thus the null hypothesis that there is no effect of body position on VEMP measurement with respect to n23 latency is rejected.**

Literature on response consistency of VEMP was reviewed by Ferber et al. (1999) based on the studies done by Cody &Bickford (1969), Townsend & Cody (1971), Colebatch et al. (1994) and Robertston & Ireland (1995). This review suggests that response consistency was not 100% in all the subjects for both the waves of VEMP. How ever, consistency is more for first wave p13 and less for second wave n23 of VEMP response. In the present study, the results suggest that there is significant difference between the latencies of n23 evoked by three different body positions. And this difference can be attributed to the possible poor response consistency of n23 as reported in the literature.

3) The effect of body position on Amplitude of p13-n23

Repeated measure analysis of variance was done to investigate the effect of body position on p13-n23 (peak to trough) amplitude. Table-5 shows the descriptive statistics of amplitude of p13-n23 of males and females across the three body positions (A, B & C).

Body position	Males		Females	
	Mean	S.D	Mean	S.D
A	48.3427	19.28879	52.9376	23.50879
B	46.4415	22.97675	54.1420	21.35789
C	50.8195	24.71197	51.5478	15.86674

Table 5. Mean & S.D of amplitudes of p13-n23 (in micro volts) in male and female subjects

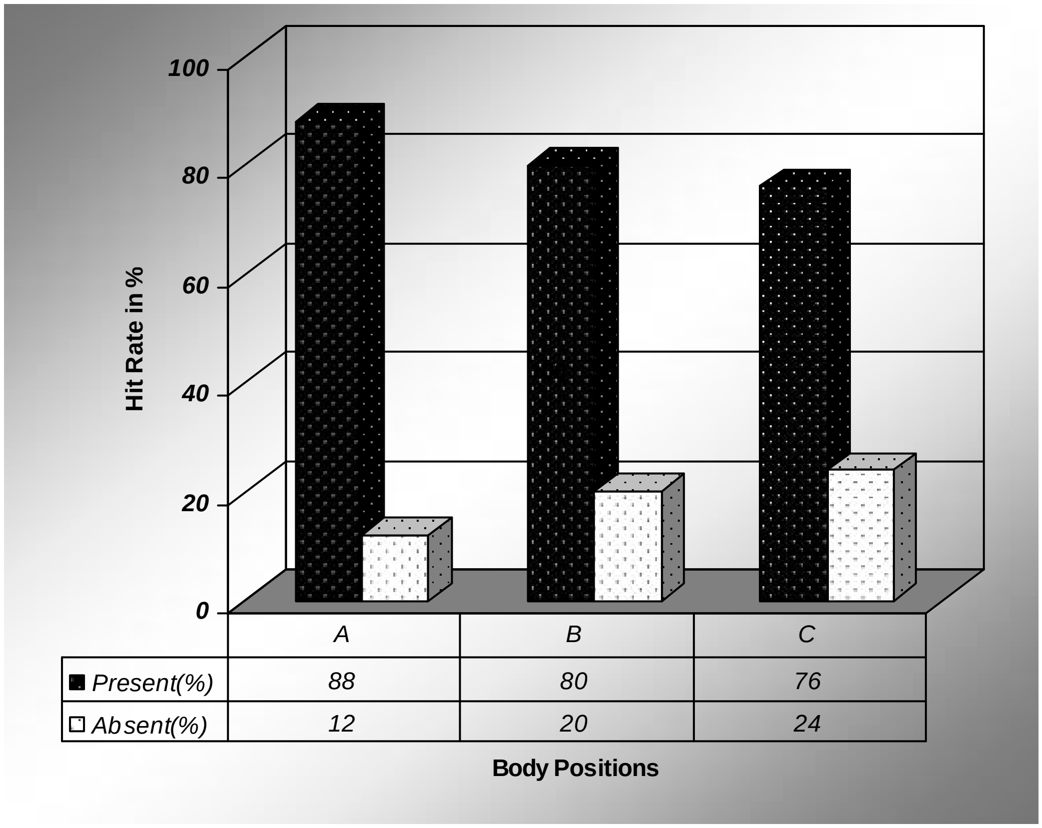
Results revealed that there is no significant difference in amplitude of VEMP between any of the three body positions in both males [F (2, 30) = 0.254, p > 0.05] as well as females [F (2, 32) = 1.088, p > 0.05] at 0.05 level of significance. **Hence, the null hypothesis that there is no effect of body position on VEMP measurement with respect to p13-n23 amplitude is accepted.**

The mean amplitude values of VEMP in the present study are not consistent with the amplitude values reported in other studies. The mean amplitudes of p13-n23 as reported by Kaushal (2006) were less in comparison to the amplitudes recorded in the present study even though the level of stimulus was 10dB lower in the present study than the level of the stimulus in Kaushal's (2006) study. The reason for this could be that the EMG level was controlled to be between 30-50 micro volts in the present study, where as it was not controlled in the Kaushal's study. It is possible that the EMG level greater than 50 micro volts would have raised the mean amplitude value of p13-n23. This further indicates that the effect of EMG level is more than that of the intensity of stimulus (short tone burst) on amplitude of VEMP response.

Huei-Jun et al. (2007) found mean amplitudes of VEMP to be 198.53 micro volts with S.D of 64.64. Mean amplitudes of present study are around 50 micro volts with S.D of around 25. Since the level of stimulus used was same in both the studies, the difference in amplitudes can be attributed to two reasons: (a) The S.D of amplitudes of Huei-Jun et al. study was higher than the S.D of the present study indicating that the group was heterogeneous thus affecting the mean, (b) The effect of EMG level was >50micro volts in Huei-Jun et al. study and this was lower than 50 micro volts in the present study (maintained between 30-50micro volts).

4) The effect of body position on Response Rate of VEMP

Graph-1 shows the descriptive statistics of response rate of VEMP for the different body positions (A, B & C) for male subjects. X-axis represents the body positions and Y-axis represents the percentage of subjects in whom VEMP could be recorded, i.e. response rate.



Graph-1. Effect of body position on response rate of VEMP in Males

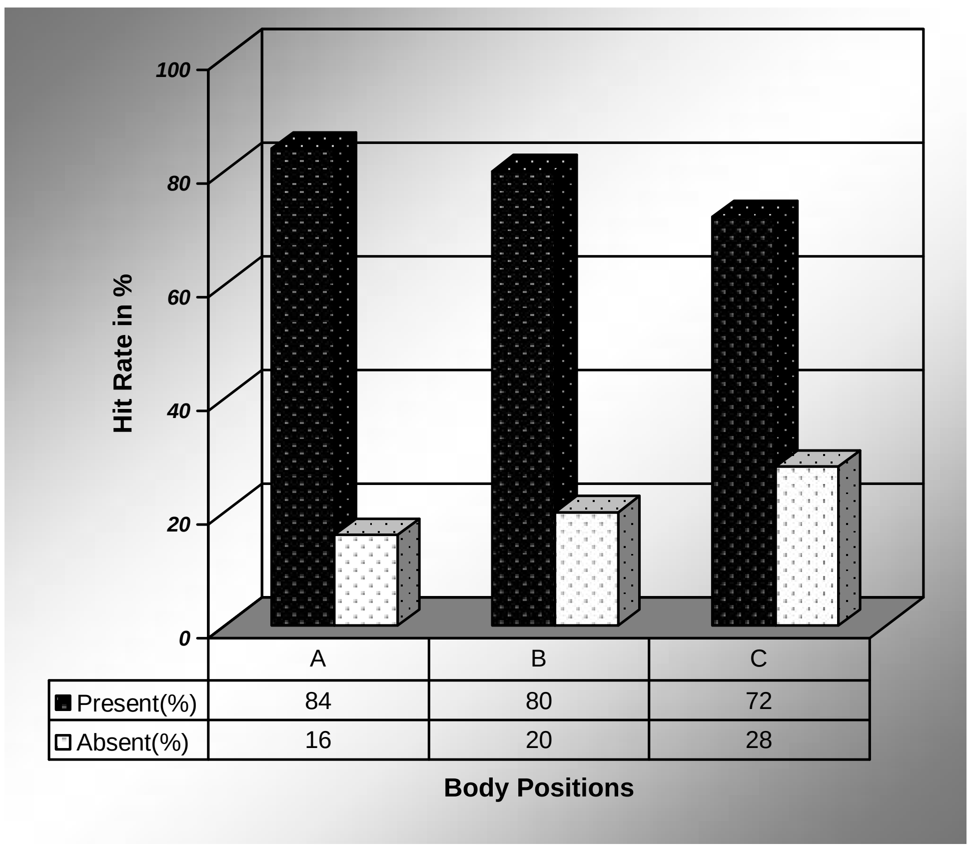
Graph-1indicates that response rate of VEMP was highest (88%) in A position and minimum (76%) response rate was obtained in C position. The following are the details of male subjects in whom VEMP could not be recorded.

- Number of subjects in whom VEMP was absent in all three positions: 02 (08%)

- Number of subjects in whom VEMP was absent in only two positions: 01 (04%) (A and B positions)

- Number of subjects in whom VEMP was absent only in one position: 06 (24%) (8%in B position and 16% in C position)

Graph-2 shows the descriptive statistics of response rate of VEMP for the different body positions (A, B & C) for female subjects. X-axis represents the body positions and Y-axis represents the percentage of subjects in whom VEMP could be recorded, i.e. response rate.



Graph-2. Effect of body position on response rate of VEMP in Females

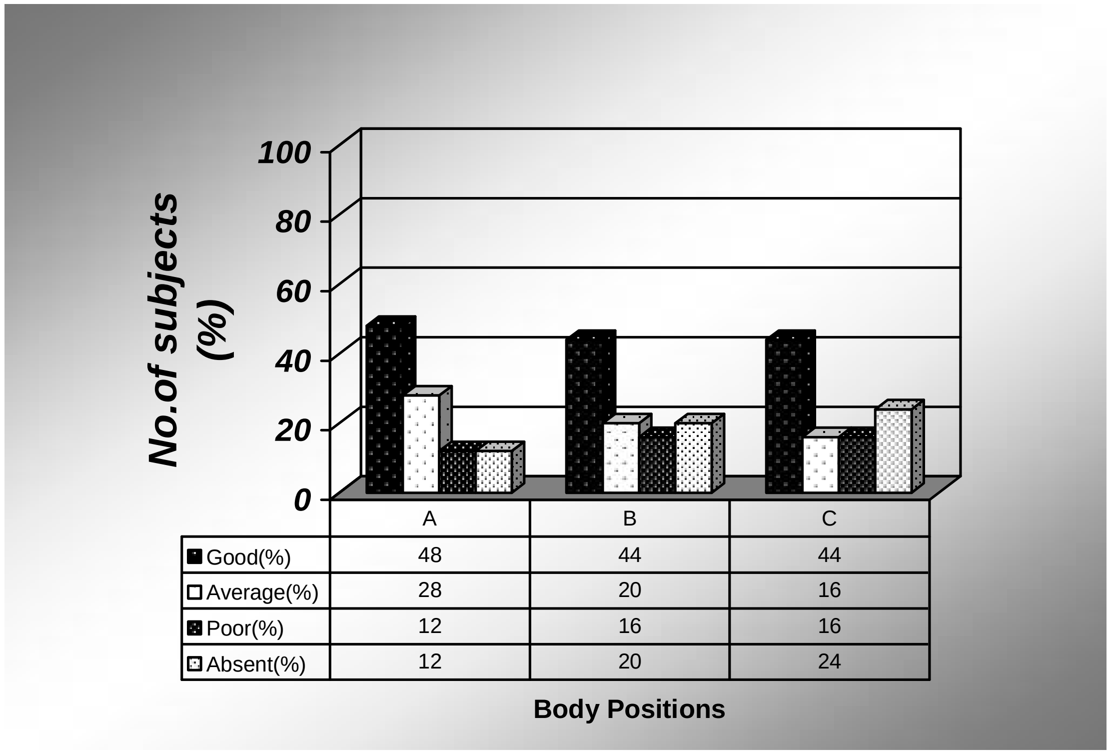
Graph-2 indicates that response rate of VEMP was highest (84%) in A position and minimum (72%) response rate was obtained in C position. The following are the details of female subjects in whom VEMP could not be recorded.

- Number of subjects in whom VEMP was absent in all three positions: 03 (12%)
- Number of subjects in whom VEMP was absent in only two positions: 02 (08%) (4% in A, C and the other 4%in B, C)
- Number of subjects in whom VEMP was absent only in one position: 03 (12%) (4% in B and 8% in C positions)

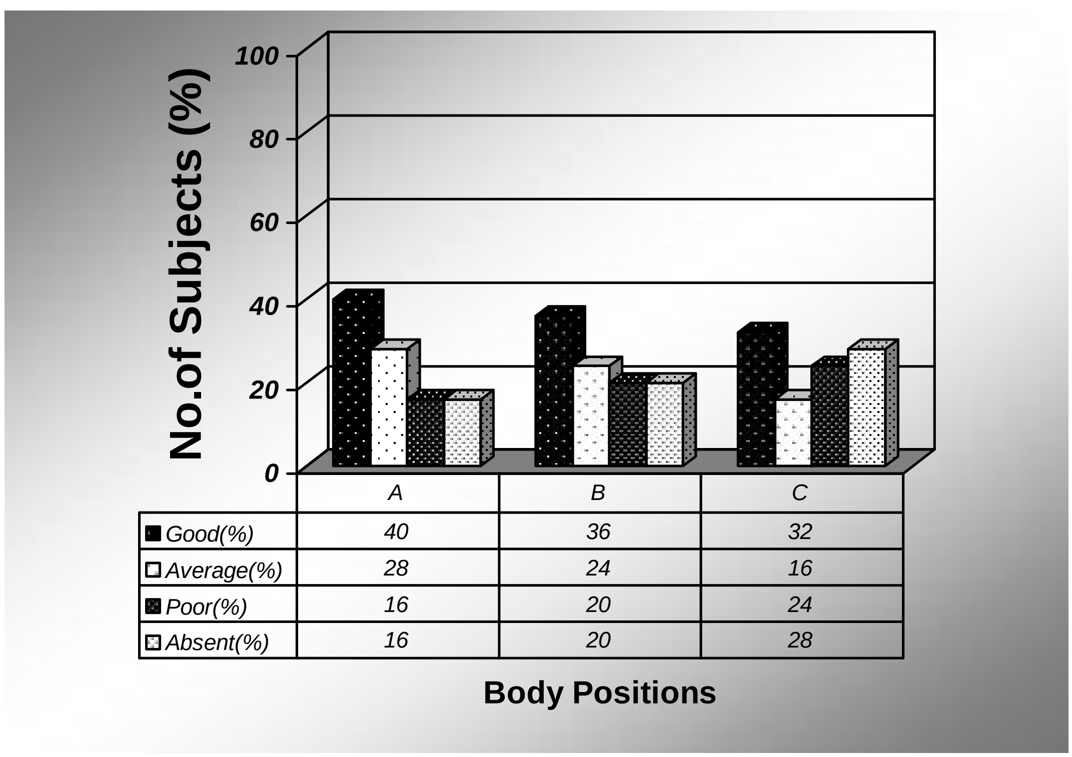
According to the present study there is not much difference in the Response rate of VEMP between the three positions and overall response rate is consistent with the response rate observed by Cody & Bickford (1969) and Townsend & Cody (1971). The number of subjects in whom VEMP could not be recorded was more for position C in both male and female subjects.

5) The effect of body position on Wave morphology of VEMP

Wave morphology of VEMP wave forms was rated using a 3 point rating scale (good, average and poor). Graph-3 & 4 shows the descriptive statistics of the rating on wave morphology of VEMP response in the different body positions (A, B & C) for male and female subjects. X-axis represents the body positions and Y-axis represents the number of subjects.



Graph-3. Effect of body position on wave morphology of VEMP in Males



Graph-4. Effect of body position on wave morphology of VEMP in Females

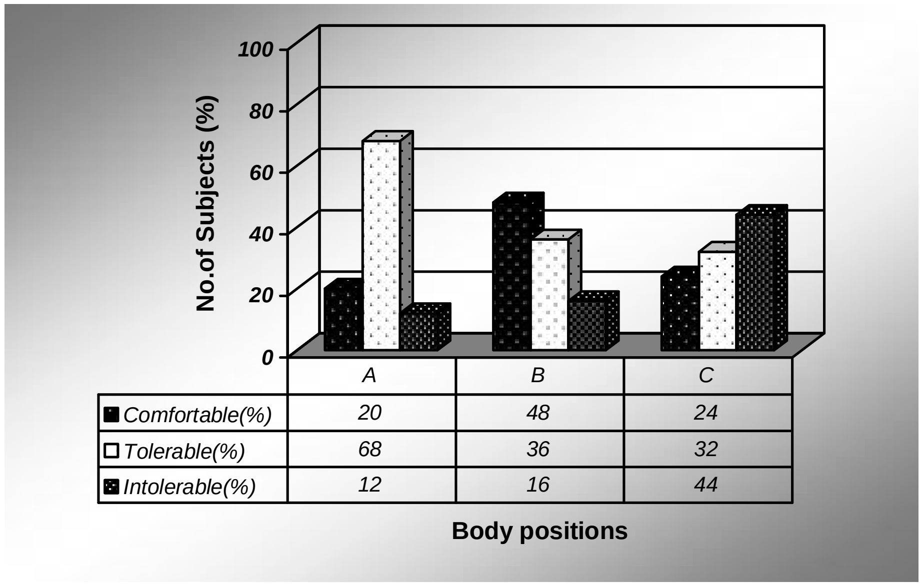
Graphs 3 & 4 show that position 'A' could evoke good wave morphology of VEMP in 48% of subjects compared to B (44%) & C (44%) positions in males. In female subjects also 'A' position has evoked good wave morphology of VEMP in 40% of subjects compared to B (36%) & C (32%) positions. But it should be noted that there was not much difference across 3 positions in number of subjects that had good wave morphology.

The present study indicates that there is difference in wave morphology of VEMP response evoked by different body positions and position 'A' evokes better wave morphology in males as well as in females.

6) Relation ship between body position and Subjects rating for comfort

All the subjects were asked to rate the body positions used in VEMP testing for the comfort level experienced on a 3 point rating scale (1-Intolerable, 2-Tolerable, 3-comfortable).

Graph-5 shows the descriptive statistics of subjective rating for comfort across different body positions (A, B & C) for male subjects. X-axis represents the body positions and Y-axis represents the number of subjects.

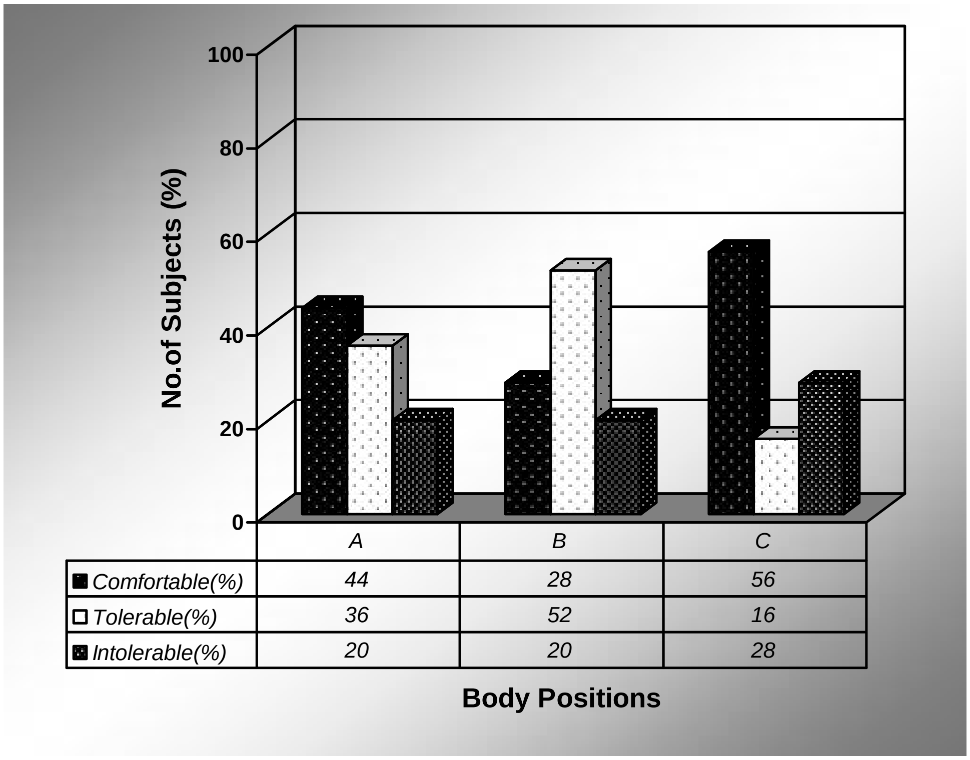


Graph-5. Relationship between body position and comfort in males

From the graph-5 with respect to male subjects it can be seen that:

- in position 'A' most of the subjects (68%) rated as tolerable, some (20%) rated as comfortable and least number of subjects (12%) rated it as intolerable
- in position 'B' most of the subjects (48%) rated as comfortable, some (36%) rated as tolerable and least number of subjects (16%) rated it as intolerable and
- in position 'C' most of the subjects (44%) rated as intolerable, some (32%) rated as tolerable and least number of subjects (24%) rated it as comfortable

Graph-6 shows the descriptive statistics of subjective rating for comfort across different body positions (A, B & C) for female subjects. X-axis represents the body positions and Y-axis represents the number of subjects.



Graph-6. Relationship between body position and comfort in females

From the graph-6 with respect to female subjects it can be seen that:

- in position 'A' most of the subjects (44%) rated as comfortable, some (36%) rated as tolerable and least number of subjects (20%) rated it as intolerable
- in position 'B' most of the subjects (52%) rated as tolerable, some (28%) rated as comfortable and least number of subjects (20%) rated it as intolerable and
- in position 'C' most of the subjects (56%) rated as comfortable, some (28%) rated as intolerable and least number of subjects (20%) rated it as tolerable

Since this is the first study to investigate the comfortness of subjects for the different body positions used to evoke VEMP response, there is no literature to compare the results of the present study with that of the others. And the results of the present study indicate that not all positions are equally comfortable to all the subjects and the position preferred by males is different from the position preferred by females. Males have preferred 'B' position i.e. subject's body rotated to one side for measurement of VEMP on the opposite side while lying in supine position and females have preferred 'C' position i.e. instructing the subject to press the Forehead against a soft surface to be comfortable for VEMP testing.

Independent samples t-test was administered to the data to investigate whether there is any significant difference between males and females for p13, n23 latencies and amplitudes of VEMP across the three positions (A, B & C). Table-6 shows the descriptive statistics of independent t-test. It shows t values for males and females with respect to p13, n23 latencies and amplitudes across the three positions

	t	df	Sig.(2-tailed)
Ap13	.662	41	.512
Bp13	.278	38	.782
Cp13	.835	35	.409
An23	.653	48	.517
Bn23	1.258	38	.216
Cn23	.719	35	.493
Aamp	.702	41	.487
Bamp	1.098	38	.279
Camp	.106	35	.916

Table 6. t values of males and females for p13, n23 latencies and amplitudes across the three positions

The present study indicates that though the male and female subjects choose different body position for VEMP testing in terms of the comfort, there is no difference between them in terms of the response parameters of VEMP (p13, n23 latencies and amplitude) in any of the body position.

Chapter-V

Summary and Conclusion

The present study was taken up to investigate the relationship between VEMP measures (latency of p13 & n23 and p13-n23 amplitude), response rate, wave morphology and subject comfort when tested in different body positions used to excite sternocleidomastoid muscle during testing. Further, it was also to see whether there is any relationship between different body positions performed by client in terms of comfort and the nature of VEMP response.

A) Subject’s body rotated to one side for measurement of VEMP on the opposite side in sitting position.

B) Subject’s body rotated to one side for measurement of VEMP on the opposite side while lying in supine position.

C) Instructing the subject to press the forehead against a soft surface.

Results from statistical analyses reveal that:

1. There was no difference in latency of wave p13 of VEMP response across the three body positions used in the study in both males as well as females.
2. There was a difference observed in latency of wave n23 of VEMP response between different positions in both males as well as females.

3. There was no difference in p13-n23 amplitude of VEMP response across the three body positions used in the study in both males as well as females.
4. There is no difference in response rate of VEMP evoked by different body positions. Almost all the three positions yielded equal response rate in both males as well as females.
5. Position A (Subject's body rotated to one side for measurement of VEMP on the opposite side in sitting position) in males and females evoked slightly better VEMP with good wave morphology. But the difference was not significant with respect to other positions
6. Position B (Subject's body rotated to one side for measurement of VEMP on the opposite side while lying in supine position) was reported to be comfortable by males and position C (Subject pressing the forehead against a soft surface) was so for eliciting VEMP response.

From the results obtained the following conclusions are tenable:

1. Irrespective of gender VEMP measures such as latencies of P13, N23 and amplitude of p13-n23 are not affected by body position that is used to excite the sternocleidomastoid muscle during VEMP testing.
2. Response rates, wave morphology of VEMP are also not affected by the body position used to excite the sternocleidomastoid muscle during VEMP testing irrespective of gender.
3. Regarding the comfort of the patient during VEMP testing, position 'B' that is "Subject's body rotated to one side for measurement of VEMP on the opposite

side while lying in supine position" was the most preferred position while testing male subjects. And position 'C' that is "subject pressing the forehead against a soft surface" was reported to be more comfortable position for females.

Limitation of the study

- Very small population was taken into the study

Implication of the study

- The study reveals that clinician while testing VEMP need not prefer any body position for better VEMP measures, one may rather consider the subject comfort in choosing the prescribed position.

Further Scope

- VEMP testing may be carried out on different age groups to explore the issue of subject comfort.
- VEMP testing may be carried out on disorder population to explore the issue of subject comfort.
- The same kind of study can be carried out with some other body positions that can excite Sternocleidomastoid muscle.
- VEMP testing may be carried out to study the effect of body positions for binaural VEMP.

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