ESTIMATION OF VESTIBULO-OCULAR REFLEX GAIN USING HEAD IMPULSE PARADIGM IN NOISE INDUCED HEARING LOSS

Aneena K

(Register No:18AUD005)

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

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CERTIFICATE

This is to certify that this dissertation entitled '**Estimation of vestibulo-ocular reflex gain using head impulse paradigm in noise induced hearing loss'** is a bonafide work submitted in part fulfilment for Degree of Master Science (Audiology) of the student Registration Number 18AUD005. 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.

Mysuru

July, 2020

Prof. M. Pushpavathi

Director

All India Institute of Speech and Hearing

Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that this dissertation entitled '**Estimation of vestibulo-ocular reflex gain using head impulse paradigm in noise induced hearing loss'** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Degree or Diploma.

Mysuru

July, 2020

Dr. Prawin Kumar

Guide

Associate Professor in Audiology

Department of Audiology

All India Institute of Speech and Hearing

Manasagangothri, Mysuru-570006

DECLARATION

This is to certify that this dissertation entitled '**Estimation of vestibulo-ocular reflex gain using head impulse paradigm in noise induced hearing loss'** is the result of my own side under the guidance of a faculty at All India Institute of Speech and Hearing, Mysuru and has not been submitted to any other University for the award of any other Degree or Diploma.

Mysuru **Registration No. 18AUD005**

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ABSTRACT

The current study aimed to estimate the vestibule ocular reflex (VOR) gain using video Head impulse paradigm in individual with and without noise exposure. The study was done in two groups of individuals comprising of a control and experimental group, each group having 15 participants in the age range of 30-55 years. The results shows than vHIT, the VOR gain was higher (better) in control group whereas in experimental group there was a reduction (poorer) in VOR gain obtained in lateral canal. Also refixation saccades and abnormal VOR gain in posterior canal was present in individual with noise exposure. Hence study concludes those individuals exposed to noise are having vestibular dysfunction in canals based on vHIT. As vHIT is non-invasive, simple, and fast tool to help in evaluating all the six semicircular canals, it can be used as a diagnostic test for evaluating vestibular function with NIHL along with other audio-vestibular test batteries.

CHAPTER 1

INTRODUCTION

Audio-vestibular system is one of the important sensory systems in human beings, which helps in hearing and balances. It is well recognized that exposure to noise or loud sound damages the cochlea, resulting in hearing impairment. Hearing impairment due to occupational noise is referred as noise induced hearing loss (NIHL). There are two kinds of mechanisms reported in literature which can cause destruction of the inner ear by noise i.e. direct mechanical destruction and metabolic decompensation with subsequent sensory elements degeneration (Oosterveld et al., 1982). Study conducted by South in 2004 reported one million people worked in noise-exposed areas, of those 1.7 lakhs experiencing serious ear damage due to noise-exposure. Less attention was paid to the impact of occupational noise on the vestibular system and remained neglected areas among professionals (Manabe et al., 1995; Ylikoski, 1988; Ylikoski et al.,1988). A very limited clinical study examined vestibular function in NIHL individuals and reported a possible correlation between the hearing impairment and vestibular dysfunction (Golz et al., 2001; Oosterveld et al., 1982; Ylikoski., 1988).

Patients exposed to noise for a longer duration also reported vestibular symptoms along with noise induced hearing loss. Studies reported vestibular abnormalities among individuals exposed to occupational noise (Manasa, 2009; Shilpashree, 2014; Wang & Young, 2007). Wang and Young in year 2007 reported 50% of the individuals exposed to occupational noise had abnormal VEMP i.e. delayed VEMP latencies leading to abnormal sacculo-collic reflex pathway. Similarly, study done by Manasa (2009) reported 51% individuals with NIHL had reduction in cVEMP amplitudes. Study done by Shipashree (2014) recorded both cVEMP and oVEMP and reported abnormal responses among NIHL individuals using cVEMP whereas oVEMP showed no differences in terms of latency and amplitude between NIHL and healthy individuals

Need for the study

Together with the cochlea, the vestibular end organ uses the same basic concept of mechanical-electric transduction with the help of sensory hair cells (Eisen & Limb 2007). High levels of industrial noise also stimulate the bony labyrinth. Patients exposed to noise for a longer duration also reported vestibular symptoms along with noise induced hearing loss. Studies reported vestibular abnormalities among individuals exposed to occupational noise (Madappa, 2009; Shilpashree, 2014; Wang & Young, 2007). Thus, the balance system has a detrimental effect along with hearing sensitivity, due to long term noise exposure.

The possible vestibular involvements in NIHL are not much studied. Most of the studies are done to find the effect on otolith organ secondary to noise exposure. Literature shows that Individual exposed to noise for a shorter or longer duration might exhibit giddiness or sway movement, Tullio phenomenon or may not exhibit any vestibular issues. Thus vHIT recording might help to unfold the semicircular canal involvement in individual exposed to noise with or without vestibular symptoms.

At present, the need of objective tests for assessing VOR gain of semicircular canals has been accomplished with the recent advancement of non-invasive , new instrument known as video Head Impulse Test (vHIT), developed by Halmagyi and Curthoys in 1988. vHIT is based on the concepts of head Impulse Test using same amplitude and high acceleration head impulse with light weighted goggles which consist of a gyroscope which help to detect the angular head movement and it also has a high speed digital camera which help to detect faster eye movement (Baloh et al., 1977; MacDaugall et al., 2009). With the brief and high velocity head impulse in the yaw and pitch axes, vHIT examines all six semicircular canals separately.

Shupak et al (1994) found that a symmetrical reduction in the vestibular response was correlated with symmetrical hearing loss. They concluded that clinical symptoms in individuals with symmetrical NIHL have low incidence may be explained by the ability of central nervous system to compensate for peripheral vestibular dysfunction, because visual and somatosensory input make up for vestibular deficits .

Tseng and Young (2013) investigated vestibular dysfunction using Audiometry, cVEMP, oVEMP and caloric testing in patients with noise-inducing hearing loss (NIHL). They found that the pars superior utricle and semicircular canals are least prone to noise exposure than the cochlea and saccule.

Yilmaz and colleagues in 2018 studied the semicircular functioning in industrial workers with NIHL. The gain of the vestibulo-ocular reflex was obtained using vHIT. Canal deficit was detected in 55.5% of the individuals in the NIHL group and was detected 6.6% of the individuals in the control group. They also reported that there was a significant reduction in VOR gain in individuals with NIHL. It is likely that NIHL individuals may have abnormal functioning of the semi-circular canal and hence it is essential to assess the different semi-circular canals. Present study will focus on assessing the VOR in all three semi-circular canals using vHIT in NIHL individuals.

Aim of the study

The present study aimed to estimate the VOR gain using Head impulse paradigm in individual with noise exposure.

Objective of the study

1) To measure the VOR gain in healthy individual using Head impulse paradigm.

2) To measure the VOR gain in individual with noise exposure using Head impulse paradigm.

3) To compare the VOR gain using Head impulse paradigm in individual with noise exposure and healthy individuals

CHAPTER 2

REVIEW OF LITERATURE

In a highly technical world, the effect of noise on the auditory system has become a major issue. Hearing loss due to occupational noise exposure is most prevalent among industrial workers. An increase in the number of individuals damaged their audio vestibular system either by continuous or intermittent noise exposure (Ylikoski et al., 1998). An estimate of one million people is working in noise exposed area, of those 1.7 lakhs experiencing serious ear damage as a result of noise-exposure (South,T., 2004).

The anatomic relationship of the vestibular labyrinth to the acoustic-energy delivery system shows higher similarity in cochlear and vestibular hair-cell ultra-structure. The vestibular and auditory receptors have common membranous labyrinth, and arterial blood supply to the cochlea and vestibular end organs through the same artery. These support the possibility of vestibular damage associated with noise induced hearing loss (Martin et al., 1998).

Individuals with NIHL also reported vestibular symptoms such as vertigo, dizziness, spontaneous nystagmus especially in those individuals who are chronically exposed to different occupational noise. Studies also reported symptoms similar to Meniere's disease among individuals with occupational hearing loss (Ylikoski., 1988).

The effect of noise on vestibular labyrinth in both symmetric and asymmetric loss of hearing was studied by Golz et al (2001). The study included 258 individuals aged 20-35 years who were extensively exposed to various loud noises. Individuals were divided based on hearing loss among them 134 suffered a symmetrical high-tone hearing loss and 124 experienced asymmetrical hearing loss. Individuals were subdivided based on the presence of vestibular symptoms such as vertigo and dizziness. Electronystagmography (ENG) was administered. The symmetrical hearing loss group had just 7(5.2%) abnormal findings in the ENG test results, including 3 asymptomatic and 4 symptomatic individuals. In the asymmetric hearing loss group, 58 individuals (46.8%) had abnormal findings, of which 32 were asymptomatic and 21 were symptomatic. There was a significant correlation between the abnormal findings in the ENG and the presence of vestibular symptoms in the asymmetric hearing loss group. There was no correlation between the NIHL's severity and that of symptoms of the vestibular and abnormal findings.

The effect of long term noise exposure on the vestibular system was studied. A dizziness questionnaire was administered on 20 factory workers who have been exposed to occupational noise for more than 10 years (age range 18-32 years) to study years. The questionnaire consist of six sections which include symptoms of dizziness, details regarding the severity of dizziness with respect to the work environment, chronology, Otological problems, General health and habits, and Vertigo functional level scale. The questionnaire examined various symptoms which occur in people with vestibular dysfunction. Seven of them emerged with vestibular symptoms. All seven individual with vestibular symptoms reported dizziness in attacks and increased severity by the end of the day. During an attack all seven participants indicated that the symptoms were usually relieved by 5–10 minutes of rest. Of the 7 people with vestibular symptoms, 4 reported that the dizziness was present for a longer duration but the other 3 reported that the dizziness passed very quickly and they were able to resume their activities (Raghunath et al., 2012). From the above study, it is clear that long term exposure to noise can induce vestibular symptoms in factory workers.

Audiological tests for vestibular assessment

There are several non-invasive procedure reported in the literature to assess different components of vestibular system i.e. cervical vestibular evoked myogenic potential (cVEMP), ocular vestibular evoked myogenic potential (oVEMP), videonystagmography (VNG), Electronystagmography (ENG), Head impulse test (HIT), Video Head Impulse Test (vHIT), and Suppression Head Impulse Paradigm (SHIMP). The functioning of otolith organs are assessed using VEMP whereas the functioning of semicircular canal is assessed using ENG, VNG and vHIT.

Vestibular findings in individual with normal hearing.

Vestibular functioning in infants using cervical vestibular evoked myogenic potential was studied by Sheykholesami et al in 2005 and compared with those obtained with normal adults. Myogenic evoked potential induced by air or bone conducted auditory stimuli recorded from sternocleidomastoid muscles in 12 neonates with different clinical finding such as Treacher Collin syndrome, Bilateral atresia and neonates who failed universal newborn hearing screening and12 normal neonates . Result revealed that with the exception of one case who failed in newborn hearing screening, reproducible biphasic VEMP was able to record from sternocleidomastoid muscle from all infants.

Felipe et al., in 2008 administered cervical vestibular evoked myogenic potential in normal individuals with an age range of 23-65 years. Cervical vestibular evoked myogenic potential was elicited at 118 dB SPL and the responses obtained as p13 and p23 latencies and peak-to-peak amplitude. There were no significant difference observed in latency of p13 and n23 comparing genders. However, statistically significant higher peak-to-peak amplitude was observed in males than females. In addition, it was also noticed that as age increases there was a decrease in amplitude of cVEMP. In another study by Janky and colleagues, effect of aging on VEMP response was studied. The study included 46 normal hearing individuals in the age group of 20 to 76 years. The students were categorized from 20 to 60 plus years into five age groups by decade. VEMP responses were measured at threshold using 250, 500, 750, and 1000 Hz tone burst and click stimuli and at a supra-threshold level to 500 Hz tone burst stimuli at123 dB SPL. Result has revealed that there were no significant differences in response to any of the stimuli between age groups for n23 latency or amplitude. In 20 to 29 years of age, substantial longer p13 latency was observed for 250, 750 and 1000 Hz relative to other age groups. Similarly significant higher threshold was observed in 500 and 750 Hz. Also, with increase in age VEMP response rate decreases (Janky et al., 2009)

Vestibular finding in individual with sensory neural hearing loss.

Saccular function using VEMP in children with early acquired or congenital sensorineural hearing loss was investigated by Zhou et al in 2009. The study includes 23 children with bilateral moderate-to-profound sensorineural hearing loss. VEMP was administered using clicks and 500 Hz tone burst as stimuli. Abnormal VEMP with sensorineural hearing loss was observed in 21 out of 23 (91%)children. The vestibular levels evoked myogenic potential thresholds were substantially higher in children with sensorineural hearing loss relative to children with normal hearing and the amplitudes were lower. There were no variations in the P1 and N1 latencies between the groups. Hearing impaired children with abnormal VEMP results may not have complaints of vestibular symptoms either due to the chronic peripheral vestibular deficiency or young children may not be able to explain the dizziness or vertigo.

Sazkar et al in 2006 studied the effects of cochlear damaging factors on the sacculocollic pathway. Fifty individual (20-60 years) with high frequency SNHL greater than 40dB HL but without vestibular pathology were tested for VEMP. The results were compared with those of 18 normal hearing individuals. Individual with high frequency SNHL greater than 40 dB HL showed significantly more saccular organ deterioration, which means the underlying mechanism can damage the cochlea as well as the saccule.

Vestibular findings in individual with NIHL

Ylikoski (1988) studied the effect of noise exposure in guinea pig with an impulse noise of 1.1 kHz at 158 dBSPL which found that excessive noise level leads to severe damage to cochlea and vestibular system. Similarly Ylikoski et al (1988) also reported that excessive effect of noise exposure on individual with different degree of hearing loss. These individuals may have sub-clinical symptoms prior to the exact occurrence of clinical symptoms with vestibular issues. Vestibular issues were mostly expressed in individual with higher degree of hearing loss than mild loss. Similarly, Aanta et al (1977) also reported symptoms of vestibular disturbance (spontaneous nystagmus, lowered caloric excitability or abnormality in rotator test) as high as 44.9% in a group of 49 male workers in the mean age range of 30 years who had been exposed to extreme noise between 6 months to 10 years. The lesions were thought to have occurred as a result of the low frequency vibrations in the peripheral vestibular system.

Smooth harmonic acceleration (SHA) test and electronystagmography were performed on NIHL individuals and result showed reduced VOR gain and reduced caloric response in these individuals (Shupak et al, 1994). In SHA and ENG test results there was no asymmetry in the parameters which was tested. Study also suggested that a centrally compensated symmetrical decrease in the response of the vestibular end organ correlated with the symmetrical hearing loss measured in the NIHL group. Further, it was also noted that there is an inverse correlation in degree of hearing loss with VOR gain as well as ENG caloric lateralization. Kumar et al (2010) studied cVEMP on 30 individual (age range 30-40 years) with NIHL .

The results showed that latency of cVEMP response was prolonged, and peak-to-peak amplitude was reduced in NIHL, as the average pure tone hearing threshold was increased. Consequently, in 67% of the NIHL subjects in this sample, VEMP was abnormal or missing. It is therefore concluded based on the study that vestibular dysfunction is closely seen in individuals with NIHL.

Shilpashree (2014) studied cVEMP and oVEMP outcome in individuals with NIHL. Ten individual (age range 25-50 years) with history of noise exposure and 10 individual (age range 25-50 years) without history of noise exposure were participated in the study. Both cVEMP and oVEMP was recorded in all the individuals. In individual with noise exposure, n13 and p23 latency of cVEMP were prolonged and n13-p23 complex amplitude was reduced. The amplitude of n1-p1 and p1-n2 complex in oVEMP was reduced in individual with noise exposure but significant difference was not observed in n2 latency of oVEMP between the groups. This finding suggests that there could be damage to sacculocollic and utriculo-ocular pathway due to long duration of exposure of noise (Shilpashree, 2014). Similarly, Madappa (2009) evaluated the functioning and susceptibility of saccule in 30 individual with NIHL in the age range of 20-35 years. Abnormal cVEMP was obtained in 61.4% of the cases with significant prolongation of p13 and reduced amplitude of p13-n23 complex and cVEMP responses were absent in 30.6% of the cases.

From these evidences it is clear that excessive or longer duration of exposure of noise can cause vestibular damage. Most of the studies are done to assess the effect of noise exposure on otolith organ whereas effect of noise exposure on semi-circular canal is not much studied. Present study further extended the literature on head impulse test/video head impulse test in normal hearing individuals or in different pathologies.

Video Head Impulse Test

Head impulse test, a simple and reliable test to identify the overt saccades, was first described by Curthoys and Halmagyi in 1988. The HIT consist of brisk head rotation in the horizontal plane to mimic a perfect angular position while subject maintain a fixed gaze on the target (Bradshaw et al., 2010). The vestibulo-ocular reflex (VOR) is a reflex activated by otolith organ and semi-circular canals. The role of VOR is to stabilize the image on the retina during head movement. The major advantage of HIT is that it can be administered in a short period of time and easy to identify saccades (movement of eyes after the offset of head movement). The limitation of the HIT was with our visual system to spot the movement of eye during the rapid head movement prohibit in identifying the covert saccades. To overcome the limitation of HIT, it was modified to Video Head Impulse Test (vHIT) by Curthoys and Halmagyi (1988) which works in the same principle as HIT at same amplitude and high acceleration.

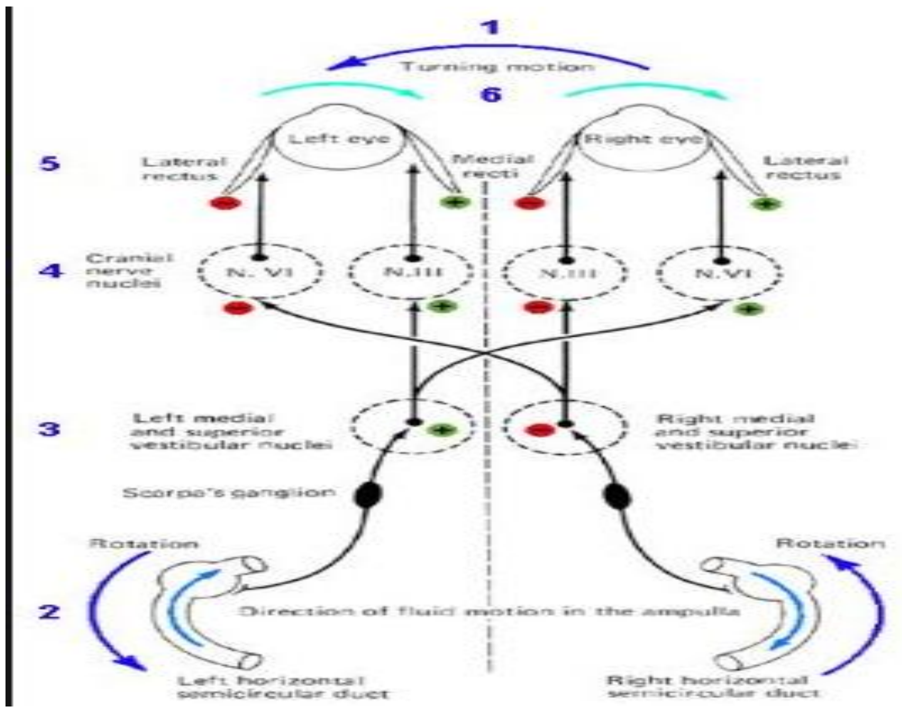

Figure 1.1: schematic representation of Vestibulo ocular reflex

Video head impulse test assesses all the three semi-circular canals independently and the response is objectively measured (Akin et al., 2014). The vHIT is accepted worldwide as a fast and accurate method in individuals with vestibular pathologies to determine the vestibular-ocular reflex. vHIT is capable of measuring overt and covert saccades which cannot be detected with naked eye. The patient has to wear a light weighted goggle which consist of a gyroscope and help in detecting the angular head movement. Further, it also has a high speed digital camera which helps to detect faster eye movement (Baloh et al., 1977; MacDaugall et al., 2009).

A novel head impulse test variant called the Suppression Head Impulse Paradigm (SHIMP), created by Halmagyi and Curthoys (2016). At the same time, the head impulse test has been called the head impulse paradigm (HIMP) .When administering SHIMP, the test subject is asked to concentrate on a laser point in front of the test person rather than a fixed point on the wall. In healthy individuals the VOR gain of HIMP was reported in the range of 0.8 to1.2 for lateral canal and 0.7 to 1.2 for vertical canal (Murnane et al., 2014; Ulmer et al., 2011). Whereas in individuals with semi-circular canal dysfunction, study reported reductions in the VOR gain (Blodow & Walther, 2013).

A Study was done by Hulse and colleagues using video head impulse test in 55 children (age range 3 to 16 years). Horizontal vestibular-ocular reflex (HVOR) was assessed using a video-oculography system device. Reproducible vHIT results were obtained in 75% of the children. The system was easily calibrated with laser dots in children. The above finding help in concluding that video head impulse test is a sensitive and efficient vestibular test in children (Hulse et al., 2015). For typically developing children and adolescents, reliability of the horizontal and vertical video head impulse test and maturation effect on angular vestibular eye reflex (AVOR) gain estimates and peak head velocities of individual canals were studied. Ross and Helminski in 2016 administered vHIT on 28 typically developing children with an age range of 4 to 17 years. The study concluded that in paediatric population, vHIT is a reliable clinical test to quantify individual canal function using high velocity head impulses. However in children, it was observed to have asymmetric compensatory eye movements when the head velocities were more than 100 degrees/s in vertical canals.

vHIT was done in 212 individuals (aged 6 to 93 years) with no history of neurological or vestibular impairment in individual in yaw axis. The mean VOR gain obtained was 1.06 with standard deviation 0.07; gain was evaluated by age and head velocity. With higher velocityimpulses it was steady until age 70 and for lower-velocity head impulses until age 90. Compensatory refixation saccades occurred in 52 individuals. The presence of compensatory saccades in individuals was significantly higher after 71 years of age. However, the reduced gain correlated with head impulse velocity with head velocity, VOR gain reduced. Hence, it was concluded that VOR gain is stable till the age of 90 years and later started declining (Matino et al., 2015).

Study done by Mossman and colleagues were administered vHIT on 60 normal hearing individual (age range of 20-80 years) with no history of neurological and vestibular pathology to establish normative data. The normative range was measured by using horizontal VOR velocity gain at 60 ms and 80 ms for both right and left rotations. vHIT was administered on horizontal plane and a mean VOR gain of 0.97 was obtained in 60 normal individuals. Horizontally administered vHIT obtained a mean VOR benefit of 0.97 in 60 normal persons. The mean HVOR velocity gain of 0.97 at 80 ms was marginally different in 60 normal individuals aged 20-80 years from that of 0.94 at 60 ms. The study revealed that with age, the VOR gain in velocity decreases slightly. Yet the HVOR velocity benefit in patients younger than 70 years was always above 0.80 at 80 ms and always above 0.76 at 60 ms (Mossman et al., 2015). However, Mcgarvie et al in 2015 measured VOR gain for all canals across a range of head velocities in healthy subjects in decade age bands (10-90 years). The results showed that the VOR gain decrease during high head velocities, but it was unaffected with increase in age. vHIT has an advantage over other vestibular test in assessing various condition related to semicircular canals in children and adult. The study was done on 30 individual (age range less than 20 years) with different vestibular pathologies such as Vestibular neuritis, BPPV, chronic subjective dizziness, Vestibular migraine, Enlarged vestibular aqueduct and superior semicircular canal dehiscence syndrome. The vestibular test such as caloric test, rotatory chair test and vHIT was performed on these individuals. Out of all three tests, percentage of abnormality was lesser in rotatory chair test and caloric test compared to vHIT test results. VOR gain was poorer in all individuals with vestibular pathologies. VHIT is therefore viewed as a test to evaluate the functioning of semi-circular in children and provides major potential benefits over rotary chair and caloric testing. (Hamilton., 2015).

vHIT in different pathologies (MD, vestibular neuritis, BPPV etc)

vHIT is an important diagnostic test to detect the involvement of semi-circular canal in Meniere's disease. A study done on 36 individual with Meniere's disease underwent vHIT in all three planes. Out of all, 12(33%) found to have normal semicircular functioning, other 12(33%) had at least one semi-circular canal functioning affected and 1 individual had abnormal semicircular functioning in unaffected ear. Hence it was concluded that gain reduction depends on onset, duration of the disease and degree of hearing loss (Santos et al., 2014). vHIT was also used as a tool for assessing and estimating the prognosis of Meniere's disease treated with gentamycin. A study was done on 31 individuals with Meniere's disease administered with a dosage of intra tympanic gentamycin and followed for 6 to 7 months.

vHIT was done before and after giving the dosage of gentamycin. The VOR gain was reduced in lateral, anterior and posterior canals respectively. Thus it was concluded that dose of intra-tympanic gentamycin bringing change in VOR gain suggested the act of dose in short term control over vertigo attack in individuals (Marquez et al., 2015).

Eza-Nunez et al in 2014 done a study on 50 individual with unilateral vestibulopathy. Twenty one out of 30 individual had compensatory refixation saccades in horizontal vHIT assessment. However VOR gain was found to be 0.91. Hence it can be concluded that vHIT on individual with complaint of dizziness suggested presence of peripheral vestibulopathy. A single case study of 42 year old individual with BPPV due to otoconia plugged in horizontal canals was reported by Mangabeira et al in 2014. vHIT and VEMP were administered before and after manoeuvres. Result revealed that VOR gain reduced and improved after 2 days of the manoeuvres administered. VEMP was found to be absent before rehabilitation and was identifiable after 30 days of manoeuvres administered. Hence vHIT can be useful in measuring the efficacy of treatment manoeuvres for BPPV.

vHIT was studied on 12 individuals with idiopathic BPPV. Normal VOR gain was observed in all the individuals and no significant variation was seen in between the same canals between the ears with BPPV where canalolithiasis was present in superior semicircular canal. However gain asymmetry found to be variants for each canal (Perez-Fernandez et al., 2014). Schubert and colleagues in 2014 reported VOR gain as one of the measure to differential diagnosis of stroke and vestibular neuritis. The study was done on 26 individuals with acute vestibular symptoms where MRI scan revealed individual with onset of stroke to have lesion at posterior inferior cerebellar artery(PICA) or anterior inferior cerebellar artery (AICA) . Out of 26 individual 16 had vestibular neuritis, 7 had AICA and 3 had PICA. vHIT was done on all individuals showed ipsi-lesioned and contra-lesioned mean VOR gain as AICA (0.84,0.74) PICA (0.94,0.93) and vestibular neuritis (0.52,0.57). Results shows that

VOR gain was symmetrical in PICA stroke which is normal, heterogeneous in AICA stroke and in case of vestibular neuritis, it was found to be asymmetrical suggesting that unilateral vestibulopathy. Taking into account, all of the above studies in various clinical populations, vHIT has good sensitivity to test peripheral vestibular functioning. VOR gain, VOR gain asymmetry and the presence of refixation saccades are taken as the various criteria for separating vestibular dysfunction in this clinical population from the normative ones.

vHIT is a good tool to use for both healthy individuals as well as with different vestibular pathologies such as Meniere's disease (Santos et al., 2014), Vestibular neuritis (Schubert., 2014), BPPV (Perez-Fernandez., 2014) with good sensitivity and specificity. It is likely that NIHL individuals may have abnormal functioning of the semi-circular canal and hence it is essential to assess the different semi-circular canals.

Tseng and Young in 2013 investigated vestibular dysfunction using Audiometry, cVEMP, oVEMP and caloric testing in patients with noise-inducing hearing loss (NIHL). Thirty individual with NIHL and 30 normal individuals were included in the study. Abnormal audiometrical, cVEMP, oVEMP and caloric test percentages were 100%, 70%, 57% and 33% respectively in NIHL. The decreasing order of abnormal percentages for cochlea, saccule, utricle and semicircular canal function following chronic noise exposure further supports that cochlea and saccule are more sensitive to noise exposure than pars superior utricle and semicircular canals Moreover, in case of semi-circular canal deficit we can see that 77 percent of NIHL individuals shows normal results.

The semicircular canal's function in industrial workers with noise-induced hearing loss was evaluated by Yilmaz et al in 2018. The VOR gain for all 6 semicircular canals was examined in 36 individuals with noise exposure and 30 healthy individuals using SYNAPSIS vHIT. Among them none of the participants had any complaints of vertigo. The mean gains for the lateral canals (> 0.80) and the anterior and posterior canals (> 0.70) have been considered normal.The result indicates that 55.5% of participants in the NIHL group were found to have an abnormal VOR gain. i.e. among them right semicircular canal (SCC) deficit was identified in 4 patients (20%), left horizontal SCC deficit was identified in 8 patients (40%), bilateral horizontal SCC deficit was identified in 5 patients (25%), right anterior and right lateral SCC deficit was identified in 1 patient (5%), left anterior SCC deficit was discovered in 1 patient (5%) and left lateral and bilateral anterior SCC deficit was detected in 1 patient. They also found dissociation between VOR gain and severity of hearing loss.

The absence of vertigo complaints in noise exposure patients can be explained by the central nervous system's ability to compensate for peripheral dysfunction of the vestibular system. Several researchers have reported that people with noise induced vestibular dysfunctionwill not have subjective balance disturbance whenever there is a gradually develo ping vestibulopathy as a result of excessive noise exposure or a significant difference betwee n the ears (Golz et al.,2001; Oosterveld et al.,1982; Ylikoski et al.,1988) .

Thus, from the above mentioned studies, it is clear that individual exposed to noise can have vestibular symptoms which suggest vestibular involvement in these individuals. vHIT is an effective tool for assessing the functioning of semicircular canals in noise-exposed individuals. There are reports of damage in otolith organs due to noise exposure. But limited studies are done to find the functioning of semicircular canals. So, the present study taken to estimate VOR gain using video head impulse tests in individuals with noise exposure.

CHAPTER 3

METHOD

Participants

The study was conducted on total 30 male participants in the age range of 30 to 55 years, out of which 15 individuals participated in each group, i.e. control group (mean age 38.7 years) and experimental group (mean age 43.6 years). Those individuals who had been regularly exposed to occupational noise for at least 5 years continuously and had either normal hearing and/or noise induced hearing loss up to mild degree were considered for experimental group. Similarly, those individuals who were not exposed to occupational noise and who had either normal hearing and/or sensorineural hearing loss up to mild degree were considered as control group.

Inclusion and Exclusion criteria

For experimental group, those individuals who were exposed to occupational noise and working in industry for 8 hours per day; 5 days in a week and from minimum duration of 5 years were participated in the study. For control group, those individuals who were not exposed to occupational noise were considered for the study. In both the groups, individuals who had any middle ear problem or conductive pathology; complaint of intolerance to sound or any retro-cochlear pathology; pain in neck region or any history of spondylitis; any known medical conditions such as Diabetes mellitus, and hypertension based on structured case history, was excluded from the study. In the study, one participant was removed due to neck pain.

Instrumentation

The below mentioned audiological equipment's was used for the present study:

1. Calibrated dual channel Inventis Piano diagnostic audiometer was used to perform pure tone audiometry and speech audiometry.
2. Calibrated GSI- Tympstar immitance meter (Version 2.0) was used for assessing middle ear functioning.
3. Calibrated ILO 296 (Version 6) system was used for measuring transient evoked otoacoustic emissions.
4. Calibrated Intelligent Hearing System (IHS) Smart EP system (Version 3.86) with ER3A insert receivers was used for click evoked auditory brainstem response to rule out retrocochlear pathology.
5. Video head impulse test was performed using GN otometrics manufactured vHIT instrument along with laptop connected otosuite software with Frenzel glasses to measure VOR gain.

Test Environment

All audiological tests were carried out in either single or double sound treated room situation. The noise levels were well within permissible limit as per ANSI S3.1 (1991). Also the individual who were exposed to noise was assessed after a gap of minimum 12-15hours.

Test Procedure

Participants in both experimental and control group was assessed using test battery approach i.e. Structured case history, pure tone audiometry, speech audiometry, tympanometry, acoustic reflexes, TEOAEs, click evoked ABR, and vHIT. A detailed case history was taken to gather information related to the inclusion and exclusion criteria from both the groups.

A questionnaire developed by Tharmar (1990) was also administered in the experimental group along with case history. Pure-tone audiometry (using Inventis piano audiometer) were done, which includes both air conduction at octave intervals between 250 Hz to 8000 Hz using TDH-39 headphones as transducer and bone conduction thresholds between 250 Hz to 4000 Hz using Radio B71 bone vibrator as transducer. The pure tone audiometry was performed using modified Hudgson and Westlake procedure (Jerger & Carhart, 1959) to obtain hearing sensitivity of each participant. Among control group, 5 had normal hearing (0-15 dBHL; Mean PTA 10 dBHL), 5 had minimal hearing loss (16-25 dBHL; Mean PTA 19.25 dBHL), and 5 had mild sensorineural hearing loss (26-45 dBHL; Mean PTA 42.5 dBHL). Similarly in the experimental group, 5 had normal hearing (0-15 dBHL; mean PTA 11.5 dBHL), 5 had minimal hearing loss (16-25 dBHL; Mean PTA 20 dBHL) and 5 had mild sensorineural hearing loss (26-45 dBHL; Mean PTA 35.25dBHL). Speech audiometry includes speech recognition thresholds (SRT) and speech identification scores (SIS) were obtained using appropriate speech materials. Speech identification score was done at 40dB SL. SRT was in correlation with PTA in both the groups. The SIS in both the groups was above 80% in Quiet.

Immittance audiometry includes tympanometry which was done using 226 Hz probe tone frequency and both contralateral and ipsilateral acoustic reflex thresholds were measured for 500, and 1000Hz. In both groups, participants had either ‘A/As’ type tympanogram and presence of acoustic reflexes at 500 Hz and 1kHz in both ears.

Transient evoked otoacoustic emission was recorded using click stimuli in non-linear mode. The click stimulus was presented at 80 dB peakSPL. The TEOAEs obtained were considered as present only when the signal-to-noise ratio (SNR) was greater than 6 dB for at least three consecutive frequencies. The DPOAEs were done whenever TEOAEs were absent. DPOAEs recorded at different distortion product frequencies and the SNR were noted. The response was considered to be present if the SNR exceeds 6 dB (Gorga et al., 1993) even for DPOAEs. In control group, TEOAEs was present in 5 normal hearing individuals, 4 individual with minimal hearing loss whereas DPOAEs was present in 1 minimal hearing loss and 5 mild SNHL individuals. In experimental group, TEOAEs were present only for 3 individuals with normal hearing whereas DPOAEs were present for 2 individuals with normal hearing, 5 individuals with minimal hearing loss and 5 mild SNHL individuals.

Click evoked auditory brainstem responses were obtained using IHS Smart EP system (Version 4.5). The individuals participated in the present study were instructed to remain relax and seated on reclining chair during the ABR testing. The electrode site was cleaned using Nuro-prop gel. The acquisition and stimulus parameters were used as mentioned in Table-2. TEOAEs/DPOAEs and click evoked ABR was done to rule out auditory neuropathy spectrum disorder.

Table 3.1 *The acquisition and stimulus parameters of auditory brainstem responses.*

STIMULIUS PARAMETERS	
Type of stimuli	Click
Duration	100 microsecond
Intensity	80 dBnHL
Repetition rate	11.1/s & 90.1/s
Polarity	Rarefaction

Total number of stimuli	1500
ACQUISITION PARAMETERS	
Analysis Time	12 ms
Filter Setting	High pass: 100 Hz Low pass: 3000 Hz
Amplification	100000
Number of channels	2
Number of recordings	2
Transducer	Insert ear phone (ER-3A)
Electrode Montage	Non inverting electrodes (+): Vertex (Cz) Inverting electrodes (-): Mastoid / Ear lobe Ground electrode: Forehead (fpz).

Individual with indication of any retrocochlear pathology based on ABR was excluded from the study. None of the participants included in the present study had identified as retro-cochlear pathology based on ABR and otoacoustic emissions.

Individuals who fulfilled the inclusion criteria based on the above audiological tests for both control and clinical group were considered for video head impulse test. Video head impulse test includes head impulse test paradigm which was done using otometric software. It consists of both hardware and software that helps to perform the test with speed and precision. The hardware includes the light weight mono-ocular goggles which has small, high speed video camera and opposite to that a mirror is placed. The mirror picked up the eye image without blocking subjects vision. There is an infrared light emitting diode that helps in clear capturing of eye movement without any distractions. For the measurement of velocity and acceleration of head movement during testing a small sensor like accelerometer is placed on the goggle. The headband attached to the goggle securely tightens it by ensuring no goggle slippage during any head impulse. This hardware is connected to the laptop having vHIT software via USB. The VOR allows the visual field to be kept in focus even during rapid head movement as head movement is followed by equal and opposite eye movement. The ratio between eye and head movements is known as VOR gain. This is used to assess the functioning of the six semi-circular canals (lateral, anterior and posterior in each ear). HIMP was done for each individual according to the protocol to assess the vestibular function of all semi-circular canals in each participant from both the groups.

Using Otosuite vestibular software video head impulse test was administered. A subject was seated on the chair such that he/she is facing the wall at a distance of 1 meter. The vHIT goggles with Frenzel glasses were positioned over the individual's eyes and the head band was tightened so that goggles do not slip even slightly during the rapid head movements. Then a laser beam was switched on which projects two laser dots on the wall placed at a distance of 1meter, adjusted for the purpose of calibration. The instrument was calibrated by instructing the individual to track the laser pointer moving alternatively to two targets without moving head. Once calibrated, the individual participated in the study was instructed to fix the gaze at the target when head thrust was given at different planes. The head thrust of 20 times was given for each plane (roll, pitch & yaw) at an angle of 10-20 degree randomly. The VOR gain was obtained for six semi-circular canals using high speed digital camera fixed in the instrument. During the testing, the head was accelerated sufficiently so that the semicircular canal which is stimulated will be excited while the other side led to inhibition of afferents. The presents of vestibular lacunae with loss of semi-circular canal function can lead to unmatching of eye velocity and head velocity which give rise to refixation of saccades to preserve the gaze stability (Jacobson, 2013; Mossman et al., 2015).

Statistical analysis

Shapiro-Wilk test of normality was done and results showed that the data had normal distribution ($p<0.05$) and hence parametric test was performed. Parametric test includes multivariate analysis of variance (MANOVA) was done to compare between groups. Descriptive statistics was done to obtain mean and standard deviation of the VOR gain for each plane of the semicircular canal in both groups. Chi-square test was done to check the association between VOR gain and the degree of hearing loss.

CHAPTER 4

RESULTS

The present study was done with an aim of estimating of vestibulo-ocular reflex (VOR) gain using head impulse paradigm in noise induced hearing loss. To check the functioning of semicircular canal using video head impulse test in individual with noise exposure and compared with individual without noise exposure. To achieve the above aim of the study, data were collected from 30 individuals (15 individual with noise exposure & 15 individual without noise exposure) and tabulated in IBM SPSS V20 software for statistical analysis.

Parametric test includes multivariate analysis of variance (MANOVA), which was done to check if there is any significant difference of VOR gain in all the planes of semicircular canal between the two groups or not. Descriptive statistics was done to obtain mean and standard deviation of the VOR gain for each plane of the semicircular canal in both groups. To check the association between VOR gain and the degree of hearing loss, Chi-square test was done.

4.1. VOR gain using Video head impulse test

Vestibulo-ocular reflex gain was calculated for each plane of the semicircular canal for both the groups. For individual with noise exposure and without noise exposure, descriptive statistics was performed to estimate the mean and standard deviation (SD) of VOR gain in both the groups in all planes of semicircular canals (Table 4.1 & Figure 4.1).

Table 4.1: *Mean and standard deviation (SD) of VOR gain for all semicircular canals for both the group.*

Planes	**Control group (N=15)**		**Experimental group (N=15)**	
	Mean	SD	Mean	SD
Right Lateral (RL)	1.04	0.06	0.97	0.10
Left Lateral (LL)	0.93	0.06	0.87	0.05
Right Anterior(RA)	0.82	0.08	0.78	0.06
Left Anterior (LA)	0.86	0.10	0.85	0.10
Right Posterior(RP)	0.79	0.07	0.73	0.19
Left Posterior (LP)	0.77	0.10	0.69	0.16

Note: N= no of participants; SD= standard deviation.

It is visible from the table 4.1 that there is a reduction in the mean VOR gain for experimental group in comparison to control group for different semicircular canals. In addition, SD for the experimental group is slightly higher for most of the canals in comparison to control group. The reductions in mean VOR gain are probably indicated poorer functioning of the different canals. The same can be visualised in the figure 4.1.

From the figure 4.1, it is evident that though there is reduction in mean VOR gain for different canals, the statistical significantly differences noticed only for right and left lateral canals.

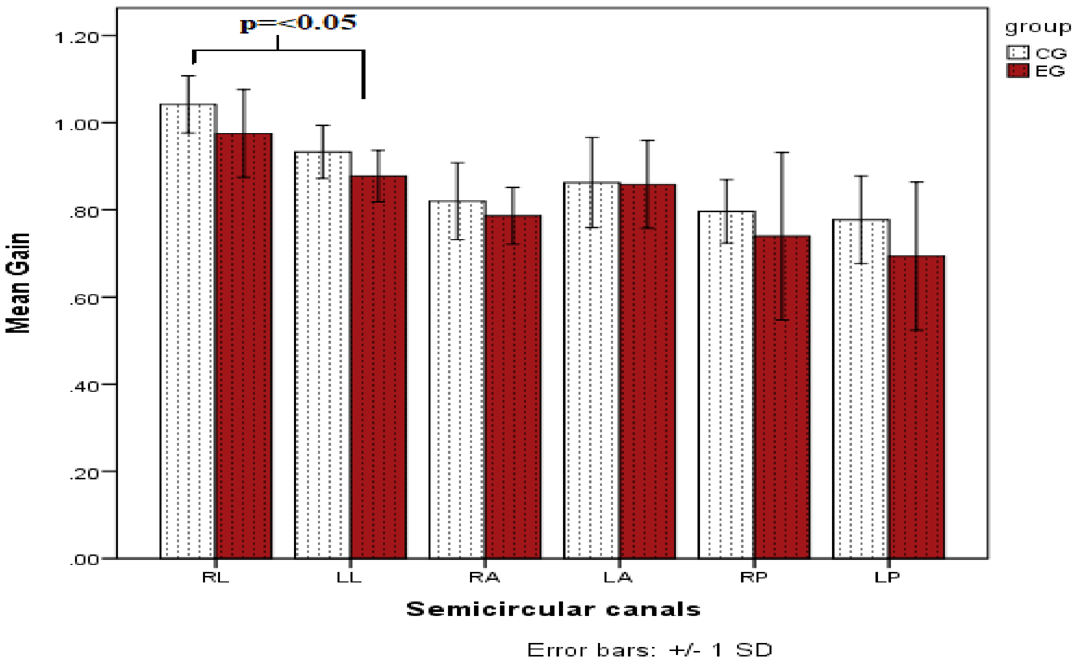

Figure 4.1: The graph represents the mean and standard deviation of VOR gain in all the planes of semi-circular canals in both the groups *(Note: RL= Right Lateral; LL= Left Lateral; RA= Right Anterior; LA= Left Anterior; RP= Right Posterior; LP= Left Posterior; CG= Control Group; EG= Experimental Group)*

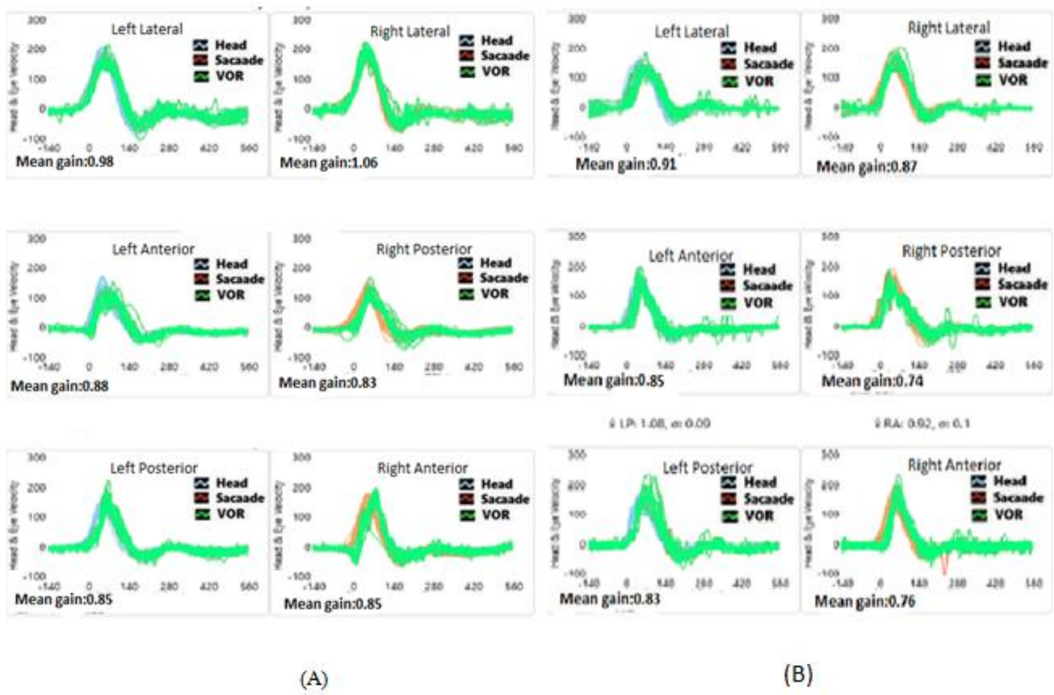

Figure 4.2: Video head impulse test results in 3 different planes of an individual (A) without noise exposure & (B) with noise Exposure.

MANOVA revealed a significant main effect between two groups for the right lateral canal VOR gain [$F (1, 28) = 4.62$, $p<0.05$], and left lateral canal VOR gain [$F (1, 28) = 6.35$, $p<0.05$]. However, there were no significant main effect between two groups reported for the right anterior canal VOR gain [$F(1,28) = 1.38$,$p>0.05$], left anterior canal VOR gain [$F(1, 28) = 0.12$, $p>0.05$], right posterior canal VOR gain [$F(1,28) = 1.16$, $p>0.05$] and left posterior canal VOR gain [$F(1,28) = 2.67$, $p>0.05$].

When the data was visually inspected and looked into it, it was observed that with reference to the normative range of the VOR gain [> 0.8 for lateral canals and >0.7 for posterior and anterior canals], reduced VOR gain was noticed in 6 out of 15 individuals (40%) in the experimental group. Among these 6 individuals, only one individual (6.6%) had left anterior SCC deficit, 6 individuals (40%) had both right and left posterior SCC deficit. However, among these 6 individuals, none of them had left and right lateral semicircular canal (SCC) deficit. Among the control group, reduced VOR gain was also noticed in 2 out of 15 individuals (13.3%) for the left posterior SCC deficit only.

4.2 Refixation saccades using Video head impulse test

The corrective saccades, i.e. overt and covert saccades, were studied in both the groups. In control group, there were no saccades observed whereas there were saccades noticeable in experimental group (Figure 4.3 & 4.4). Refixation saccades were observed in only 7 (46 %) out of 15 individuals in the experimental group. Table 4.2 represents the presence of refixation saccades in each semicircular canal in experimental group. Similarly, figure 4.3 and 4.4 represents the presence of covert, overt and combination of both saccades in individuals with and without noise exposure respectively.

Table 4.2 *represents the presence of refixation saccades in each semicircular canal in individual with noise exposure.*

Semicircular canals	Covert saccades	Overt saccades	Covert and Overt saccades	None
Right Lateral (RL)	1	2	2	10
Left Lateral (LL)	1	1	1	12
Right Anterior (RA)	3	0	0	12
Left Anterior (LA)	1	0	0	14
Right Posterior (RP)	3	1	1	10
Left Posterior (LP)	6	1	1	7

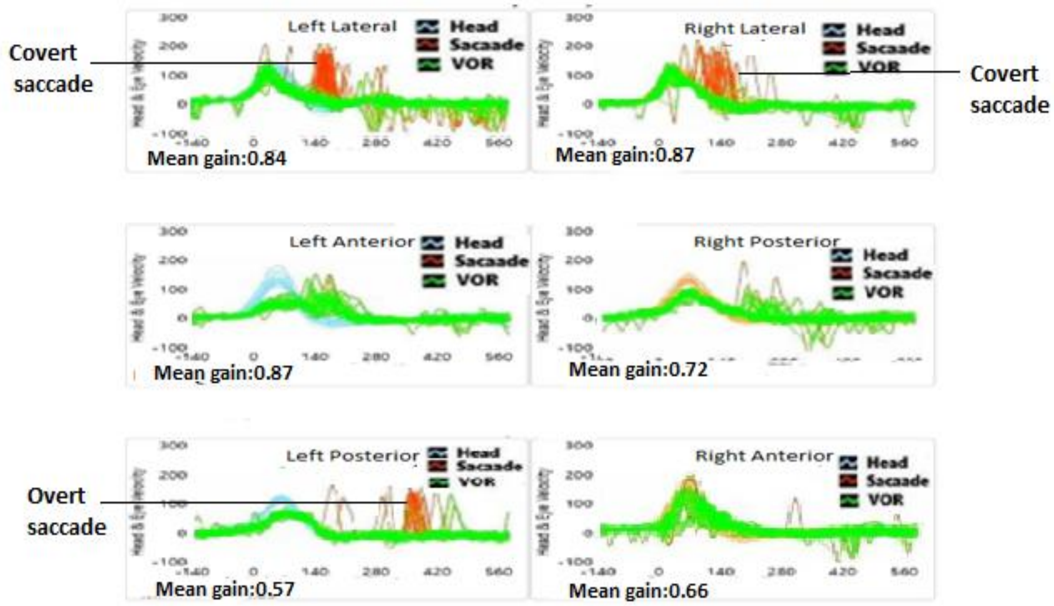

Figure 4.3: Represents the presence of covert, overt and combination of both saccades in individuals with noise exposure (Experimental group).

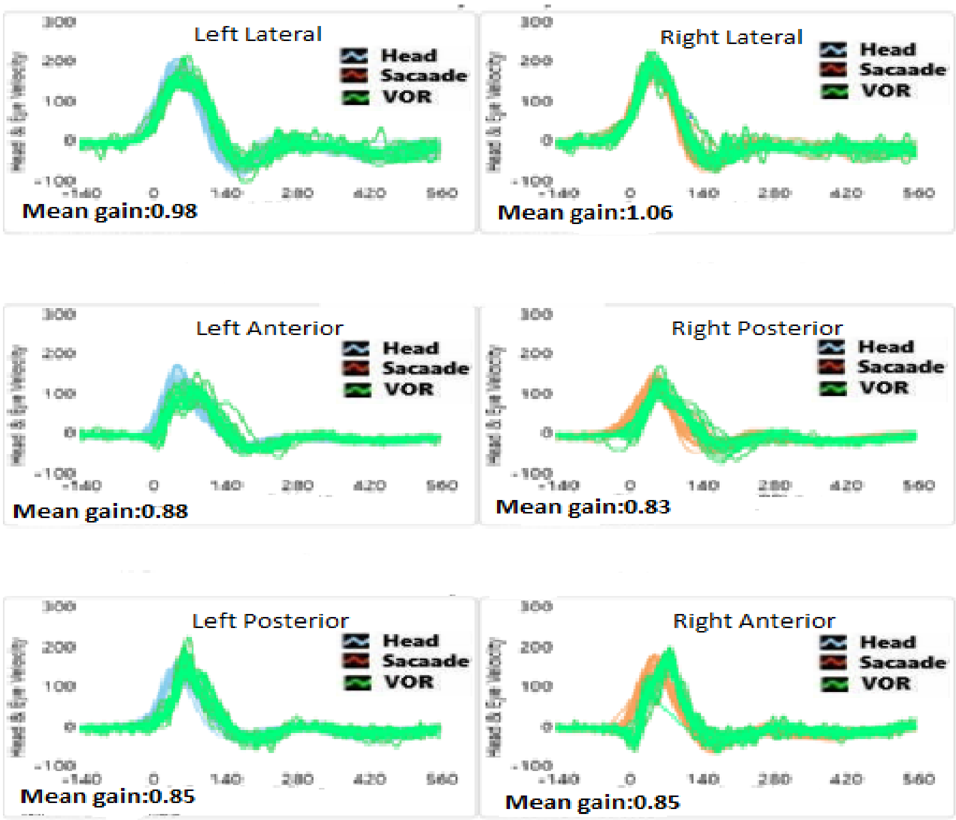

Figure 4.4: Represents the presence of covert, overt and combination of both saccades in individuals without noise exposure (Control group).

4.3. Association of VOR gain with degree of hearing loss.

Chi-square test was done to check if there is any association of VOR gain with degree of hearing loss in specific ear in individual with noise exposure. The Chi-square test showed no significant association between any of the canals and degree of hearing loss for both control group as well as experimental group (Table 4.3 & 4.4). Table 4.3 and Table 4.4 represent the association of degree of hearing loss and VOR gain in right and left ear respectively.

Table 4.3: *Association of degree of hearing loss and VOR gain in right and left ear in individuals without noise exposure.*

	SCC	Df	p-value
Right ear	Lateral	16	0.599
	Anterior	22	0.521
	Posterior	20	0.242
Left ear	Lateral	18	0.191
	Anterior	18	0.523
	Posterior	20	0.397

Table 4.4: *Association of degree of hearing loss and VOR gain in right and left ear in individuals with noise exposure.*

	SCC	Df	p-value
Right ear	Lateral	22	0.521
	Anterior	24	0.462
	Posterior	28	0.363
Left ear	Lateral	28	0.363
	Anterior	22	0.347
	Posterior	24	0.462

To conclude, Video head impulse test finding revealed significant difference in VOR gain in the right and left lateral canals in both the group but there was no significant difference in both anterior and posterior canals in both sides. Refixation saccade (covert, overt and combination of both) was present in 46% of the individuals with noise exposure. Further, no association was seen between any of the canals and degree of hearing loss in both the groups.

CHAPTER 5

DISCUSSION

5.1 Video head impulse test.

Video head impulse test was used to measure the VOR gain, which is a non-invasive procedure to assess the functioning of semicircular canals of the vestibular system in individual with noise exposure. Results from the video head impulse test were subjected to various statistical analyses and the outcome is discussed under below mentioned sub-heading:

5.1.1. VOR gain of Video head impulse test

In the present study, the VOR gain showed statistically significant differences between two groups only for both right and left lateral canal. However, there were no significant differences noticed for the right and left anterior and posterior canal between groups. Present study finding is in consonance with other studies in literature (Yilmaz et al., 2018; Tseng & Young, 2012). Study done by Yilmaz and colleagues in year 2018 were reported reduction in VOR gain, based on head impulse test in individuals with noise exposure. The study reported 55% of individuals with noise exposure had reduction in VOR gain in either one or more canals. Among them, significant reduction in VOR gain was seen in lateral canals. Similar finding is also reported by Tseng and Young (2012). They suggested it could be due to the longer exposure of noise which might be damaging the cochlear hair cells along with damage to the semicircular canals and utricle. However, considering the individual data, in the current study it was noticed that 40% individuals in the experimental group had abnormal VOR gain in posterior canals. This could be explained as since the superior vestibular nerve innervates the lateral and superior semicircular canals while the inferior vestibular nerve supplies to the posterior semicircular canal. Hence, it is hypothesised that there could be a secondary damage to vestibular nerves attached to the posterior canal.

One of the study done by Wang and young (2007) discussed about vestibular impairment among individuals with noise exposure based on the finding of vestibular evoked myogenic potential, Caloric test, and rotator chair test of vestibular assessment. They reported reduced responses in the above mentioned vestibular test in individual with noise exposure.

5.1.2. Refixation Saccades of Video head impulse test

In the present study, 46% of the individual with noise exposure had presence of refixation saccades and none of the individual without noise exposure had presence of saccades. Present study finding is in agreement with study done by Yilmaz et al (2018). Yilmaz and colleagues reported 55% of individuals with noise exposure had refixation saccades in either one or more canals. Refixation saccades are indicating an impaired semicircular canals in which individuals are unable to retain the gaze stability with movement of eye in equal velocity and opposite direction to that of head direction (Weber et al, 2008). These phenomena arises due to the difference between the stimulated sides of the co-planar axis to that of the non-stimulated side making the VOR to generate a compensatory eye movement to maintain the gaze during the head movement.

Based on the above finding, probably it indicates that these individual with vestibular impairment due to long term exposure of noise leads to difficulty in maintaining the gaze stability during head movement. Hence, these saccades help in gaze stability but not with slow compensatory eye movement. During high velocity eye movement of these refixation saccades avoid smearing of image at the retina due to inadequate VOR which leads to clear visual stimulus. Thus, presence of refixation saccades might be taken as an indicator of vestibular dysfunction in individual with noise exposure.

In the present study, none of the individuals had any complaint of vestibular symptoms though they were exposed to noise on regular basis. The absence of vestibular complaints in individuals with noise exposure can be explained by the central nervous system's capacity to compensate for peripheral vestibular malfunctions. Some studies have reported that individuals with vestibular impairment caused by noise will not experience subjective balance impairment, since the chronic vestibulopathy caused by noise is slowly evolves or u nless there is an asymmetrical hearing loss between the ears (Oosterveld et al.,1982; Shupak et al., 1994).

It is also important to note that semi-circular canals are more resistant to damage compared to otolith organs (Tseng & Young, 2013). In addition, in the present study, most of the participants in experimental group were using ear protective devices during working hours, which might be one of the reasons for having less substantial reduction in VOR gain and the absence of refixation saccades i.e. only in 53% of the individuals exposed to noise.

5.2 Association of VOR gain with degree of hearing loss

In the present study, there was no association observed between VOR gain and degree of hearing loss. Present study finding is in support of the study done by other researchers (Yilmaz et al., 2018; Madappa, 2009; Kumar, 2014). Study done by Yilmaz and colleagues reported no association with degree of hearing loss. In a similar line, study done by Madappa (2009) and Kumar (2014) using cVEMP and Caloric test, which showed dissociation with hearing loss.

CHAPTER 6

SUMMERY AND CONCLUSION

Hearing impairment due to occupational noise is referred as noise induced hearing loss (NIHL). NIHL can be permanent or temporary. Two mechanisms can cause destruction of the inner ear by noise, i.e. direct mechanical destruction and metabolic decompensation with subsequent degeneration of the sensory elements. Short term exposure to noise with normal hearing returning after a period of rest leads to temporary hearing loss. Prolonged exposure to high level of noise gradually leads to permanent damage.

The present study was conducted with an aim of estimating the VOR gain using Head impulse paradigm in individual with noise exposure. The objective of the study were to measure the VOR gain in healthy individual using Head impulse paradigm, to measure the VOR gain in individual with noise exposure and to compare the VOR gain in both groups.

In the present study, two groups of participants in the age range of 30 to 55years were included. Control group consist of 15 participants who were not exposed to any kind of occupational noise and had either normal hearing and/or up to mild sensorineural hearing loss. Experimental group included 15 participants who were exposed to occupational noise for at least 5 years continuously and had either normal hearing and/or up to mild degree noise induced hearing loss. Video Head Impulse Test (vHIT) was administered using otometric software.

The result reveals that in control group, VOR gain obtained are within normative in each semicircular canal and none of the individuals had presence of refixation saccades. Where as in experimental group there is a statistically significant reduction in VOR gain in lateral canal but there is was no statistical significant reduction in VOR gain obtained in anterior and posterior canal. Refixation saccades were present in 40% of the individuals with noise exposure in any one of the semicircular canals. Also there was no association between VOR gain and degree of hearing loss.

Over all present study conclude that individual exposed to noise can have vestibular dysfunction in both the sides. As vHIT is non-invasive, simple, fast, and practical and also helps in evaluating all the six semicircular canals, it can be used as a diagnostic test for evaluating vestibular function with NIHL along with other audio-vestibular test batteries. Thus individual with NIHL shall be assessed for vestibular dysfunction. If any of the individuals with NIHL exhibit any vestibular signs or symptoms, the vestibular test batteries should be administered along with the preliminary audiological tests, and adequate rehabilitation plan should also be initiated. The combination of different vestibular tests also helps to distinguish between central and peripheral lesions which help to implement adequate rehabilitation.

6.1 Clinical Implications

- The findings of the present study can be utilized to see the effect of noise exposure on functioning of the different semicircular canals in the early stages of NIHL.
- The findings of the present study can be utilized for the possible management strategies in individuals with NIHL

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