Effectiveness of Subjective Visual Vertical and Video Head Impulse Test in assessment of Vestibular function in individuals with Mixed Hearing Loss

Sarga K

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSURU-570 006

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CERTIFICATE

This is to certify that this dissertation entitled **"Effectiveness of Subjective Visual Vertical and Video Head Impulse Test in assessment of Vestibular function in individuals with Mixed Hearing Lo**ss**"** is a bonafide work submitted in part fulfillment for degree of Master of Science (Audiology) of the student Registration Number: 18AUD034. 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

Dr. M. Pushpavathi
Director
All India Institute of Speech and Hearing
Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that this dissertation entitled "**Effectiveness of Subjective Visual Vertical and Video Head Impulse Test in assessment of Vestibular function in individuals with Mixed Hearing Loss**" has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
July, 2020

Guide

Dr. Sujeet Kumar Sinha
Associate Professor
Department of Audiology
All India Institute of Speech and Hearing
Manasagangothri, Mysuru-570006

DECLARATION

This is to certify that this dissertation entitled **"Effectiveness of Subjective Visual Vertical and Video Head Impulse Test in assessment of Vestibular function in individuals with Mixed Hearing Loss"** is the result of my own study under the guidance of Dr. Sujeet Kumar Sinha, Associate Professor, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru, ***Registration No. 18AUD034***

July, 2020

Dedicating this Dissertation to myself

Aknowledgement

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Abstract

Aim: the aim of the present study was to assess the functioning of the utricle and semicircular canals and its associated pathway using video head impulse test (v-HIT) and subjective visual vertical (SVV) in individuals with mixed hearing loss.

Method: 15 individuals between the age of 18 to 40 years with unilateral or bilateral moderate to moderately severe mixed hearing loss were evaluated using SVV and v-HIT, and the results were compared with the results of 15 normal-hearing individuals.

Results: There was no statistically significant difference in the mean VOR gain of the mixed hearing individuals in the right lateral, left anterior and left posterior semicircular canal when compared to the normal group, but a significant difference was noted between the groups in for VOR gain of left lateral, right anterior and right posterior semicircular canals. However, there was no significant difference in the ocular tilt in SVV at any of the three static head positions in the mixed hearing loss group with respect to the control group.

Conclusion: The present study revealed dysfunction of few semicircualr canal in mixed hearing loss individuals. However, the SVV findings were within the normal limits in both the groups. Although SVV alone couldn’t yield any significant result in mixed hearing loss, SVV and v-HIT together is a good tool in assessing and diagnosing vestibular dysfunction in mixed hearing individuals.

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Chapter-I

Introduction

The inner ear consists of the vestibular system as well as the auditory system. The vestibular system includes three semicircular canals, utricle, and saccule. The three semicircular canals respond to change in the angular moment of the head, whereas the utricle and saccule respond to linear acceleration in vertical and horizontal planes respectively. Vestibular-evoked myogenic potentials are the gold standard test, which can effectively assess the function of utricle and saccule. cVEMP determines the function of the saccule and its innervating structures and oVEMP assess the function of utricle and its innervating structures respectively.

Dizziness accounts for 3 to 5% of all visits to the emergency department and can increase to as much as 10% of adult visits to the emergency department. The number of dizziness-related emergency department visits doubled from 1995 to 2004 (Kerber, et al. , 2008). Previous studies found peripheral vestibular disorder in 24 to 43% of dizzy patients in the emergency department (Newman-Toker, et al. , 2009)

Hearing loss is the most common human sensory impairment in industrialized countries affecting more than 5 per cent of people. It is a major health issue for the elderly, and 40% of the population aged 65 years and above has a hearing loss that is sufficiently high enough to impair communication (Davis, 1990; Ries, 1994). Also, vestibular symptoms are reported by one-third of the general population (Cohen & Gorlin, 1995). A common cause of audiovestibular dysfunction is middle ear disease. Therefore, it is highly essential to consider the importance of the incidence or history of middle ear disease in patients with vestibular disorders and its treatment by ear surgery (Agrup et al. , 2007).

According to previous studies, Glue ear is one of the most frequent causes of vestibular disturbances among pediatric population (Casselbrant et al., 1995). Acquired cholesteatoma is a type of inflammatory disease of the chronic suppurative middle ear, which most often occurs secondary to the chronic otitis media.Chronic inflammation associated with accumulation of keratin can lead to progressive degradation of the ossicular chain and adjacent bone, resulting in loss of hearing, vestibular dysfunction and facial paralysis (Agrup et al., 2007). Hence it is noted that the assessment of the vestibular system in mixed hearing loss is important as it causes damage to the vestibular end organs in the later stages.

Vestibular Evoked Myogenic Potential, Electronystagmography using Caloric stimulation, Video Head Impulse Test is the most popular clinically used objective tests to assess the integrity of the vestibular system. Other tests, which include Subjective Visual Vertical, Subjective Visual Horizontal, Rotational Chair Testing, and Computerised Dynamic Posturography, are not so commonly used in Diagnosis.

1.1 Need for the study

1.1.1 *Need for Video Head Impulse Test in individuals with Mixed Hearing loss*

Caloric testing has been a standard gold test in assessing the vestibular system. By comparing between the two ears, it provides quantitative and qualitative information about the vestibular system. Since it evaluates the vestibular function at very low frequencies, it can not distinguish whether the dysfunction is stagnant or in an active recovery state of recovery. It is very effective in identifying peripheral vestibular pathologies, it fails many times due to its time consuming nature, evoking severe vestibular symptoms, inapplicability to infected ears (SOM, CSOM), and inability to identifying vestibular neuritis affecting the inferior vestibular nerve branch(Hyo & Kim, 2012).

Water caloric testing is typically contraindicated in patients with chronic otitis media (COM), and a closed-loop system or air caloric test is an alternative choice.

However, COM may change the middle ear anatomy and may even trigger labyrinthine dysfunction, leading to the question of whether caloric findings in COM patients are accurate in representing vestibular function (Lee et al., 2009). There have been a few studies on the caloric test in patients with chronic otitis media (COM) (Barberet al., 1978) and the size of the tympanic membrane perforation and a previous history of an ear surgery have been revealed to affect caloric test outcomes(Paparella et al., 1979). Thus, caloric findings in patients with COM are hard to interpret, particularly when they complain of dizziness or vertigo. Recently it was noted that the incidence of anomalous caloric results among COM patients was high and well associated with abnormalities in rotational chair testing (Gianoli & Soileau, 2008).

The Video Head Impulse Test (v-HIT) evaluates the vestibulo-ocular reflex (VOR) and is anatomically associated with the activity of the semicircular canals in the peripheral vestibular system, motor nuclei the brain and the extra-ocular muscles (Alhabib & Saliba, 2016). v-HIT exposes hypofunction of the vestibular system by calculating VOR gain reduction and presence of covert or overt saccades. The VOR gain is measured by an objective comparison of head velocity to the eye velocity during a sudden high degree jerk to the head. Loss of function of even a single semicircular canal can lead to deficits in VOR gain(Aw et al., 1999) and appearance of refixation saccades, which can be overt or covert(Alhabib & Saliba, 2016). v-HIT yields fast, unbiased objective results and has improved sensitivity compared to the cHIT test. Measured covert saccades can also occur with central compensation and are often missed outin cHIT. v-HIT can be an excellent clinical tool in assessing the functioning of semicircular canal in individuals with mixed hearing loss as it is not affected by the status of middle ear. Study shows abnormal behaviour results in 80% of patients with vestibular neuritis 9 to 39% of patients with acute cerebellar or brainstem stroke (Guler et al., 2017).

v-HIT has several advantage over Caloric testing as it does not evoke any unpleasant vestibular symptoms during testing, head movements are more natural stimuli to the vestibular system than temperature change, it is very quick and assesses all six semicircular canals and does not require a dark room to perform the test. Research have shown that in the case of vestibular neuritis, the sensitivity of v-HIT increases to 86.7% and the specificity to 100% when the caloric deficit is between 40 and 65% (Bartolomeo et al., 2014). The authors also conclude that the caloric test is not mandatory if an abnormal vHIT confirms the unilateral weakness.

The caloric test stimulates at a low frequency, while the v-HIT stimulates at a high-frequency rate. Few Other studies also show that the sensitivity of vHIT in Meniere 's disease increased to 86.7% and its specificity to 100% when the caloric deficit is between 40 and 65 per cent (Walther & Blodow, 2013). All these studies show that v-HIT has a definite advantage over the Caloric test in terms of convenience as well as the effectiveness in identifying the pathologies affecting the vestibular system.

1.1.2 Need for Subjective Visual Vertical in individuals with Mixed Hearing loss

Among the two vestibules utricle and saccule, utricle is responsible for detecting linear acceleration in the vertical plane, and utricle in the horizontal plane. Studies in vestibular function suggest that impairment in utricle will not cause any true vertigo but general unsteadiness during walking (Pelosi et al., 2013). There are only two tests available in assessing the functions of utricle; they are ocular-Vestibular Evoked Myogenic Potential (o-VEMP) and Subjective Visual Vertical test.

Vestibular-evoked myogenic potential is a successful clinical tool that measures the integrity of the vestibular system by measuring the change in tonicity of muscles post acoustic stimulation. However, this tool fails to elicit a response when there is a loss of conduction via middle ear and external ear such as Otosclerosis (Zhou et al., 2012), perforation of the Tympanic membrane, Chronic Otitis media (Lee et al., 2014). A simulated conductive hearing loss with an ABG gap of 22.66 $\pm$ 4.2 8 dB resulted in a decrease in response rate from 100% to 38.1 % for o-VEMP and 69.1 % for c-VEMP (Han et al., 2016). Few other studies found that patients with Conductive Hearing Loss whose ABG was greater than 20 dB typically showed no response for air conducted for c-VEMPs (Halmagyi et al., 1994). Therefore it is challenging to assess the otolithic functions of individuals with vestibular symptoms when there is a conductive component or mixed hearing loss.

Subjective visual vertical is a test that assesses the function of the utricle by measuring the extent of ocular tilt (deviation of estimation of mental perception of verticality). SVV test is completed by the subject aligning a line at their perceived vertical and then measuring the deviance from the gravitational vertical (0 degree). Studies have shown that individuals with normal utricular function can set the line within 2 degree of deviation (Neal , 1926) whereas individuals with the utricular function will have a larger variation of 8 to 10 degrees in the acute stages(Curthoys et al., 1991)

Studies show that SVV test could separate healthy subjects from abnormal subjects in individuals with Parkinson's disease vestibular neuritis, Pisa syndrome, vestibular schwannoma, BPPV, acute phase of Meniere’s disease, chronic neck pain and multiple sclerosis (Shirejini et al, 2018). Vibert and Safranet (1999), measured SVV in healthy subjects and individuals with unilateral vestibular loss including vestibular neuritis, viral labyrinthitis. He report that the tilt of SVV towards the affected side in 50% of the patients suffering from viral labyrinthitis as well as vestibular neuritis.

1.2 Aim Of The Study

The present study aimed to investigate the effectiveness of the Video Head Impulse test and Subjective Visual vertical test in assessment of the semicircular and utricular function in individuals with mixed hearing loss.

1.3 Objectives of the Study

The objectives of the study was to assess the functioning of the utricle and semicircular canals in individuals with mixed hearing loss using Subjective visual vertical (SVV) and Video head impulse test (v-HIT).

Chapter- II

Review of Literature

The inner ear houses the hearing as well as the balancing organs where the cochlea is responsible for hearing and the vestibular system, which includes otolithic organs, and the three semicircular canals are responsible for balancing. The semicircular canals which are perpendicular to each other senses the angular acceleration and the otolithic organs-utricle and saccule senses the linear acceleration and are also responsible for perception of verticality.

Vestibular symptoms are reported by one-third of the general population (Cohen & Gorlin, 1995). Middle ear diseases are a common cause of audiovestibular dysfunction. Hence it is highly essential to consider the importance of the incidence or history of middle ear disease in patients with vestibular disorders and its treatment by ear surgery (Agrup et al., 2007). Caloric testing has been a standard gold test in assessing vestibular system, but it fails many times due to its time-consuming nature, evoking severe vestibular symptoms, inapplicability to infected ears (SOM, CSOM), and inability to identifying vestibular neuritis affecting the inferior vestibular nerve branch (Hyo & Kim, 2012). The Video Head Impulse Test (v-HIT) is an excellent tool that measures the vestibular-ocular reflex (VOR) more conveniently and can be used to assess the VOR in the presence of a conductive pathology.

Vestibular-evoked myogenic potential (VEMP) is a successful clinical tool that measures the integrity of the vestibular system by measuring the change in tonicity of muscles post acoustic stimulation. However, this tool fails to elicit a response when there is a loss of conduction via middle ear and external ear such as Otosclerosis (Zhou et al., 2012), perforation of the Tympanic membrane, chronic otitis media (Lee et al., 2014). Since the conventional Air conduction VEMPs fail to assess the functioning of utricle in the presence of a conductive pathology, SVV is an excellent tool that is simpler than VEMP.

2.1 Clinical application of video head impulse test

2.1.1 Meniere's Disease

Blödow et al. (2013) studied horizontal VOR in 117 individuals with the peripheral vestibular disorder, which included twenty one individuals with Meniere's disease (MD), using v-HIT and compared the results with a control group of twenty healthy subjects. They found that normal horizontal VOR gain was 0.96 ± 0.08, while an abnormal horizontal VOR gain of 0.44 ± 0.20. they reported an incidence of 54.5% abnormal v-HIT in Meniere's disease population. They concluded that v-HIT can be used as a tool in assessing VOR deficits in individuals with Menieres disease.

Blodow et al. (2014) compared the results of caloric testing and v-HIT in thirty subjects with Menieres disease and twenty three subjects with Vestibular Migraine and to determine which test is more sensitive to reveal a peripheral vestibular hypofunction. They analyzed the canal paresis factor in the caloric test and the horizontal VOR gain on both sides in v-HIT and found that the v-HIT showed horizontal VOR deficit in 37% in Menieres disease subjects. They also reported that 28% of patients with an abnormal caloric test had a normal v-HIT, whereas 6% of the subjects who had an abnormal v-HIT had a normal caloric test. They also reported that the sensitivity of v-HIT compared to caloric testing was 55% for Menieres disease. It was noted that amoung the Meniere's disease or vestibular migraine population, neither the caloric test nor v-HIT could detect any significant differences between the early stage (<5 years) or the advanced stages (>5 years) .

Manzari et al. (2011) evaluated six subjects with early Meniere's disease (stage I and II) using v-HIT in various phases of their disease (quiescence, attack & just after the attack) with at least one measure for each phase. In their investigation, v-HIT measures shows that VOR gain is typically enhanced during the quiescence period, and there is a decrease in VOR gain during the time of the acute Meniere's disease attack and a gain value approximates to normal values shortly after.

2.1.2 Vestibular neuritis

Weber et al. (2008) measured VOR with search coils during manually applied horizontal HITs of varying accelerations in thirteen patients with vestibular neuritis and fifteen patients with unilateral vestibular deafferentation and compared it to thwelve healthy subjects. They reported that patients with Vestibular Neuritis and Unilateral vestibular damage showed larger VOR gain asymmetry compared to the normal control group.

Blödow et al. (2015) did a study in sixty nine patients with sporadic vestibular schwannoma to investigate the horizontal vestibulo-ocular reflex pathway with caloric test and video head impulse test (v-HIT). They reported that AR-Gain in v-HIT detected more abnormal cases, that is 44% of cases compared to Mean-Gain in v-HIT which was abnormal in 36% of cases with vestibular neuritis.

Kim and Kim (2012) retrospectively investigated v-HIT responses in nine patients with a diagnosis of isolated inferior vestibular neuritis and reported abnormal head-impulse test (HIT) only for the involved posterior semicircular canal.

Schmid-Priscoveanu et al. (2001) compare results of quantitative head-impulse testing using search coils neuro-otology with eye-movement responses to caloric irrigation in ten patients with acute and fourteen chronic unilatera5e2el vestibular hypofunction after vestibular neuritis. They reported pathological gain reductions of the horizontal vestibulo-ocular reflex (VOR) during head impulses to the affected side compared to the contralateral side.

Zellhuber et al. (2014) evaluated ninteen patients diagnosed with unilateral vestibular neuritis, with at least two examinations at different points in time, and with the first examination up to 5 days after symptom onset. The tests always included, in addition to the clinical examination, a v-HIT, a caloric bithermal irrigation, SVV, and fundus photography was done on the same day. They reported no linear association within the group and individually with the unilateral weakness of bithermal caloric irrigation tests for the gain asymmetry and the ipsilesional gain of the v-HIT.

2.1.3 Mixed hearing loss

A common cause of audiovestibular dysfunction is middle ear disease. Therefore, it is highly essential to consider the importance of the incidence or history of middle ear disease in patients with vestibular disorders and its treatment by ear surgery (Agrup et al., 2007). Acquired cholesteatoma is a form of chronic suppurative middle ear inflammatory disease, most frequently occurring secondary to chronic otitis mediaChronic inflammation associated with accumulation of keratin can lead to progressive degradation of the ossicular chain and adjacent bone, resulting in loss of hearing, vestibular dysfunction and facial paralysis (Agrup et al., 2007). Hence it is noted that the assessment of the vestibular system in mixed hearing loss is important as it causes damage to the vestibular end organs in the later stages.

There is a lack of research in assessing VOR in mixed hearing loss individuals; hence it indicates a need to do v-HIT in determining VOR in individuals with mixed hearing loss.

2.2 Clinical implication of subjective visual vertical

2.2.1 Meniere's disease

Voß et al. (2019) evaluated subjective visual vertical (SVV) and Subjective trunk vertical (STV) in twenty six patients with Menieres disease and thirty nine healthy volunteers. They stated that the Subjective Trunk vertical was not affected by the presence of unilateral Menieres disease, while the affected side was indicated by pathologic SVV values, if present. These findings suggest that the STV does not only rely on utricular function but also on extracranial afferent signals, and may not be drastically affected by the presence of a hydropic peripheral vestibular lesion.

Bronstein and Agarwal (2010), The subjective visual vertical test was done to investigate whether patients with Meniere 's disease had otolithic dysfunction during an acute attack and to what extent.They reported that a patient with Meniere’s disease shows an abnormal ocular torsion in an acute attack. This suggested the possibility of abnormal ocular torsion consisted of a dysfunction of both the posterior semicircular canal and the otolithic organs.They also reported that the phases when nystagmus eventually vanished in patients with Meniere 's disease having abnormal tilts in acute attacks did not always correspond to normalization of SVV.The abnormal tilts of SVV observed during the attacks continued longer than the nystagmus.

Kumagami et al. (2009) studied SVV performed before, at, and after acute attacks on twenty two patients with unilateral Ménière's disease who showed normal tilts of SVV before acute attacks. They reported that fourteen (63.6 per cent) out of twenty-two cases of unilateral Ménière 's disease displayed irregular SVV tilts in acute attacks toward the side of the affected ear in 13 (92.9%) of them. However, abnormal tilts returned to normal within a few weeks after the acute attacks in twelve (85.7%) of the fourteen cases with unilateral Ménière's disease. In a large number of patients with Ménière 's disease, they found that Otolith dysfunction occurred in acute attacks, and SVV is a valuable method for evaluating otolithic fuction.

2.2.2 Vestibular neuritis

Toupet et al. (2014) evaluated 254 individuals suffering from vestibular neuritis using SVV. They reported that the subjects with vestibular neuritis have an abnormal ocular tilt towards the affected side in the acute stage of the disease. They also reported that the recovery from SVV tilt seemed to be influenced by the side of neuritis, with a faster normalization in the case of left-side involvement than with a right deficit. They noted that the recovery from SVV correlated with the resolution of the vertiginous symptoms in the pathologic group.

Min et al. (2007) did a study on thirty five patients with unilateral vestibular neuritis. All the subjects underwent Subjective visual vertical (SVV), Subjective visual horizontal (SVH), and Dizziness Handicap Inventory (DHI) before and after rehabilitation, and they compared the results. They reported that the deviation in the SVV and SVH significantly improved after rehabilitation in individuals with vestibular neuritis, along with the improvement in the symptoms. They concluded that SVV and SVH could be used as the predictor of recovery from the peripheral damage after the attack of vestibular neuritis.

Vibert and Safran (1999) studied the Subjective visual vertical with a binocular test (vertical frame) and a monocular test (Maddox rod) in patients with various types of peripheral vestibular diseases such as viral labyrinthitis, vestibular neuritis and compared the findings after unilateral surgical deafferentations such as vestibular neurectomy and labyrinthectomy. They reported that all patients, after vestibular neurectomy and labyrinthectomy, the Subjective visual vertical showed a 10-30 degrees tilt with the vertical frame, 5-15 degrees with the Maddox rod. They also reported that Subjective visual vertical tilt with the vertical frame was greater than2 degrees in viral labyrinthitis (47%) and in vestibular neurectomy (37%), whereas with the Maddox rod was greater than 4 degrees tilt in viral labyrinthitis (41%) and in vestibular neurectomy (42%). In the study, they concluded that the occular tilt in SVV was directed toward the affected ear in acute peripheral vestibulopathy, such as viral labyrinthitis and vestibular neurectomy.

Kim et al . (2008) conducted a study on fifty-one vestibular neuritis patients to compare semicircular canal recovery patterns and otolithic dysfunction with ocular torsion, subjective visual vertical and vestibular evoked myogenic potential and channel function tests including head-shaking nystagmus (HSN), caloric stimulation, and head-thrust tests. They reported abnormal tilt of SVV in 48 out of 51 participants (94%).

2.2.3 Benign Paroxysmal Positional Vertigo

Gall et al. (1999) studied SVV on sixteen patients with posterior canal BPPV baseline, post Hallpike & Semont maneuvers, and at follow-up two weeks later. They reported that Ten of sixteen patients had significant change in SVV post Hallpike maneuver. These results were also compared with the SVV of control group and they found even more significant number of patients, fourteen of sixteen had a significant difference when compared to the control group post Hallpike.

Hong et al. (2008) did a retrospective study on SVV in twentythree patients with BPPV and compared it with twenty normal hearing subjects before and during eccentric rotation toward the right and left. They found no difference in the SVV results between the groups pre-eccentric rotation, but significant variations of SVV values during eccentric rotation. They concluded that SVV during eccentric rotation can be used to identify utricular dysfunction in BPPV patients and suggest that eccentric rotation may be a successful tool for evaluating utricular dysfunction.

Von Brevern et al. (2006) measured subjective visual vertical and Otolith-ocular reflex in twelve patients with unilateral idiopathic BPPV one week and one month after successful treatment with positioning maneuvers and compared with twentyfour healthy subjects. They found no difference in the estimation of the subjective visual vertical between patients and controls; whereas in subjects with BPPV the otolith-ocular reflex was smaller than in the control group.

Böhmer and Rickenmann (1995) evaluated subjective visual vertical in the upright and side positions in twenty five normal subjects and seventy three patients with various peripheral vestibular disorders. They reported, in 100% of patients with vestibular nerve section and Ramsay Hunt syndrome, 89% of patients with vestibular neuritis, and 0% of patients with benign paroxysmal positional vertigo had a substantial deviations of SVV (to the affected ear).

Chapter- III

Method

The present study aimed to investigate the effectiveness of Video Head Impulse test and Subjective Visual vertical in assessment of semicircular and utricular function in individuals with mixed hearing loss. To meet the aim, two groups of participants were included for the study.

Group 1 included participants with moderate to severe mixed hearing loss, whereas group 2 included individuals with normal hearing sensitivity in the age range of 18-40 years.

3.1 Participants

3.1.1 Participant selection criteria Group I

- All the participants had moderate to moderately severe mixed hearing loss.
- The participants did not have a presence or history of any obvious vestibular disorders such as Meniere's disease, vestibular neuritis, labyrinthitis, BPPV or any other central or peripheral vestibular disorders.
- Individuals with any neurological symptoms were excluded from the study.
- Individuals who were undergoing any treatment for Diabetes or Hypertension/Hypotension were excluded from the study. Participants with presence or history of any spondylitis were excluded from the study.

3.1.2 Participant selection criteria for Group II

- All participants had both Air conduction and bone conduction threshold within 15 dBHL.
- Individuals did not have a presence or history of any obvious vestibular disorders such as Meniere's disease, vestibular neuritis, labyrinthitis, BPPV, or any other central or peripheral vestibular disorders.

- The participants did not have any conductive pathology or history of conductive pathology.
- Individuals who were undergoing any treatment for Diabetes or Hypertension/Hypotension were excluded from the study.
- The presence of any retro cochlear pathology was ruled out for all the participants.
- Participants with spondylitis were excluded from the study.

3.2 Instrumentation.

- A calibrated audiometer Inventis Piano with TDH-39 headphones, housed in MX-41/AR (Telephonics, Farmingdale, NY, USA) ear cushions was used to track the pure tone audiometry thresholds and administer speech audiometry among all participants. Radio ear B71 bone transducer (Radio ear, KIMMETRICS, smithsburgh, Maryland, USA) headset was used to estimate the threshold for bone conduction.
- Middle Ear Analyzer Gradson- Stadler Incorporated (GSI) Tympstar (GSI VIASYS Healthcare, WI,USA) was used to obtain the tympanogram pattern, peak static admittance, tympanometric peak pressure, equivalent ear canal volume and acoustic reflex threshold in each of the selected participants.
- Head impulse test paradigm was done using ICS Impulse OTOsuite vestibular software version 1.2 (GN Otometrics, Denmark).
- The ocular tilt of subjective visual vertical was measured using BioMed Jena GmbH Biomedizinische Technik (BioMed Jena GmbH Biomedizinische Technik, Germany)

3.3 Test environment

Ambient noise levels in an acoustically treated single room set up was maintained within the permissible limits [ANSI S3.1-1999 (R2003)]

3.4 Procedure

3.4.1 Case History

A detailed case history of each participant was taken before the testing protocol. The case history was taken to ensure the participants met the selection criteria for further testing.

3.4.2 Pure tone Audiometry

All the participants underwent routine Audiological evaluation, which included Pure tone audiometry. Air conduction thresholds was done between 250 to 8kHz,whereas bone conduction thresholds was calculated between 250 to 4kHz. Respectively by using Modified Hughson and Westlake method given by Carhart & Jerger (1959). Pure tone average was calculated with the four frequency AC threshold of 250, 500, 1k, 2k Hz. Respectively.

3.4.3 Immittance Evaluation:

Immittance evaluation was done using a 226 Hz probe tone signal. Ipsilateral and contralateral acoustic reflex threshold were elicited at 500, 1k, 2k & 4k Hz. Frequencies to confirm the middle ear pathology/ conductive component in group 1, whereas to rule out any middle ear pathology in participants of group 2.

3.4.4 Video Head Impulse Test

v-HIT responses was recorded using a GN Otometrics (GN Otometrics, Taastrup, Denmark) instrument. The person was seated in an upright position with the goggles attached with the monocular camera tightly secured on individual’s eyes. Testing started with the calibration procedure by asking the participant to follow the laser dots on a wall, which was presented alternately 10 degrees on either side of the midpoint. After calibration the individual were asked to maintain their gaze on a target which was displayed on the front wall, nearly 1 meter away from them. The testing was administered in 3 different planes i.e. Lateral plane testing for Horizontal Semicircular canals (SCC) and the LARP/RALP plane testing for the vertical semicircular canal.

To check horizontal semicircular canals, the head movements was done in a lateral plane. The examiner suddenly gave a short and brief head thrust (in the yaw plane) randomly. The Head of the participant was moved about 10-15degree with an average peak velocity of 100 to 200 degrees per second. For the lateral plane assessment, the peak velocity was maintained a minimum of 150 degrees/ second, and 20 head thrust was given for each side of the canal. And for Vertical canal assessment, the peak velocity was maintained at a minimum of 100 degrees/ second. To evaluate the anterior and posterior SCCs, the head movements were done in left anterior-right posterior (LARP) and right anterior-left posterior (RALP) plane. The Head of the participant was moved 35 degrees to the right for LARP plane testing and vice versa for RALP plane. Head thrust was applied about 10-15degree with a peak velocity minimum of 100 degrees per second in an up and down manner. 20 head thrust was given for each canal.

For each head thrust, the head and eye velocity and the ratio of head and eye velocity was measured through the software on a computer screen. Along with this, the examiner also looked for saccades to check whether these are normal or abnormal.

3.4.5 Subjective Visual vertical test (SVV)

SVV was administered in a sound-treated room with the subject seated upright position with the VR goggles tightly and securely place on the eye. Calibration was done with the static head position where the gyroscope measures the head position with respect to the gravity. The subject was instructed to maintain the head position with the goggles on. SVV test procedure started with an inclined line appearing on the LED screen of the VR goggles where the subject had to adjust the line exactly to the vertical position with the joystick provided and had to mark the position by pressing the response switch on the joystick. The trial continued with another line appearing on the screen with a different angle, where the subject had to continue the test for 5 trials. The deviation from the 0 degree was recorded for each trial and the average deviation of 5 trials was be calculated.

The second part of the SVV testing was continued with a head tilt of 30degree towards the right, where the examiner adjusted the subject's head position to a 30° towards the right, and the subject was asked to maintain the head position for 5 trials. Subjects were instructed to adjust the line to the previous vertical position and not parallel to the nasal plane. Responses were recorded, and the average deviation from 0degree for 5 trials was calculated. The test was aborted if any discomfort to the subject is noted and repeated from the beginning once the subject was comfortable. The same was repeated to the left 30degree head tilt and average deviation from 30degree was calculated for fivetrials.

3.5 Data analysis

3.5.1 Analysis of video head impulse test

- VOR gain was calculated by dividing the eye velocity to the head velocity and for both the groups.
- , The presence of any overt and covert saccades, were also marked if any.

3.5.2 Analysis of Subjective visual vertical.

- Ocular tilt was calculated by taking the grand average of the deviation from the 0° in the static head position as well as 30 degree head tilt to the right and left for both the groups.

Chapter-IV

Results

The present study was designed to assess the functioning of the utricle and semicircular canals and its associated pathway using video head impulse test (v-HIT) and subjective visual vertical (SVV) in individuals with mixed hearing loss. To achieve the aim of the study, 15 individuals with unilateral or bilateral mixed hearing loss were evaluated using SVV and v-HIT, and the results were compared with the results of normal hearing individuals. For v-HIT, vestibuloocular reflex gain (VOR gain) and the presence of any refixation saccades were measured. For SVV, average ocular tilt form 0degree was measured at 30-degree head tilt on either side.

4.1 video head impulse test in individuals with normal hearing and individuals with mixed hearing loss

VOR gain was measured for three different planes of semicircular canals; lateral plane, RALP plane & LARP plane for all 30 participants (group I and group II). The presence of any saccades was also noted.

The representative waveform of the v-HIT result of lateral, LARP, RALP planes of an individual with normal hearing is given in Figures 4.1 and 4.2 and 4.3, respectively.
The representative waveform of the v-HIT result of lateral, LARP, RALP planes of the individual with mixed hearing loss is given in Figure 4.4 and 4.5 and 4.6, respectively.

Out of the 15 participants of the mixed hearing loss, it was observed that a total of nine (60%) had presence of saades in the v-HIT testing; out of thte nine, four had overt and covert saccades, four had only overt saccades and one person had only covert saccade. None of the participants in Normal Hearing group had presence of overt or covert saccades.

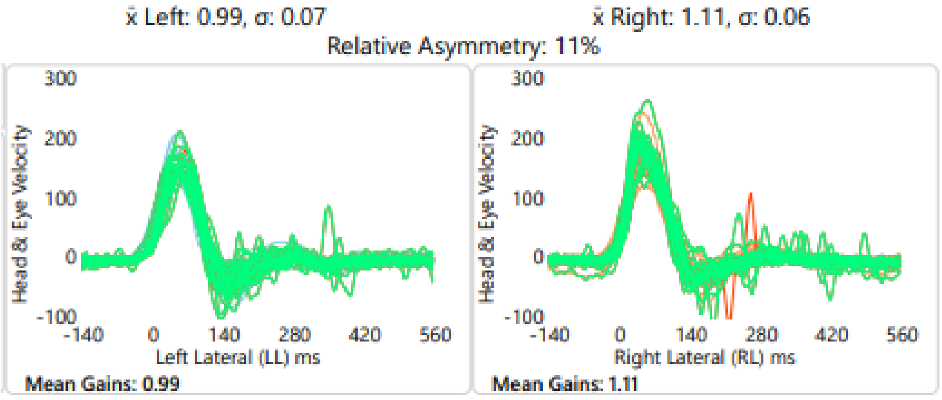


Figure 4.1 *Mean VOR gain of lateral plane in one individual with Normal Hearing*

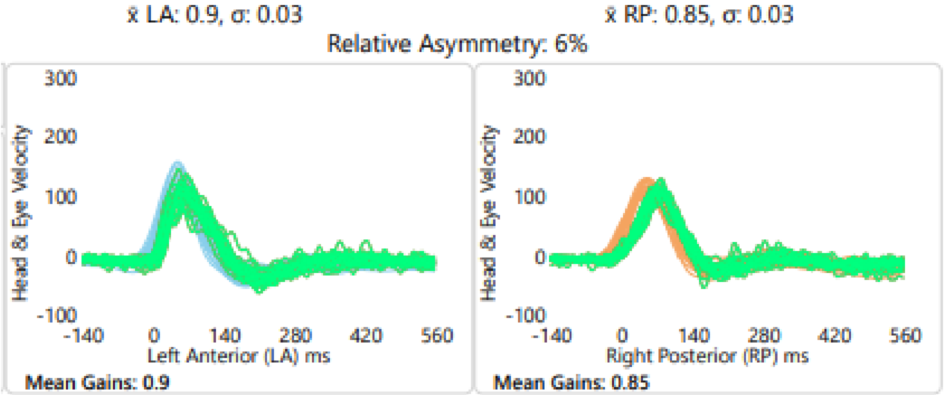


Figure 4.2 *Mean VOR gain of LARP plane in one individual with Normal Hearing*

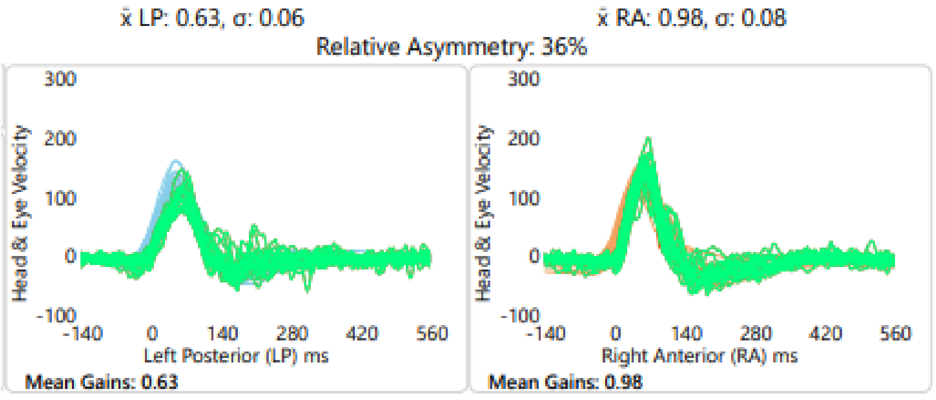


Figure 4.3 *Mean VOR gain of RALP plane in one individual with Normal Hearing*

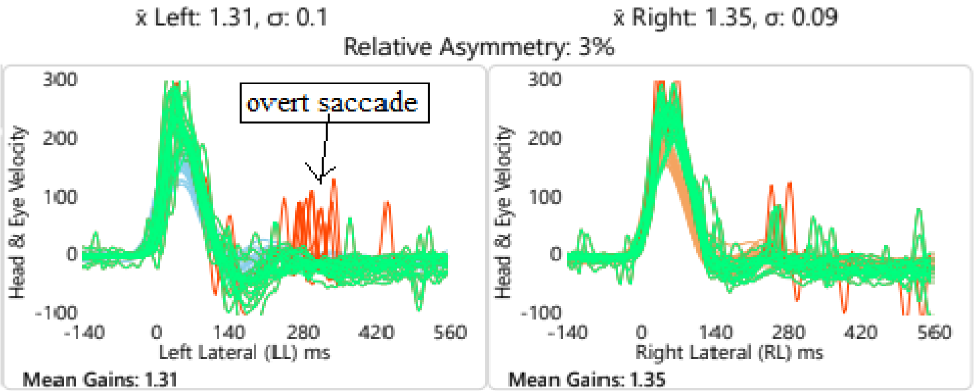


Figure 4.4 *Mean VOR gain of lateral plane in one of the individuals with Mixed Hearing loss*

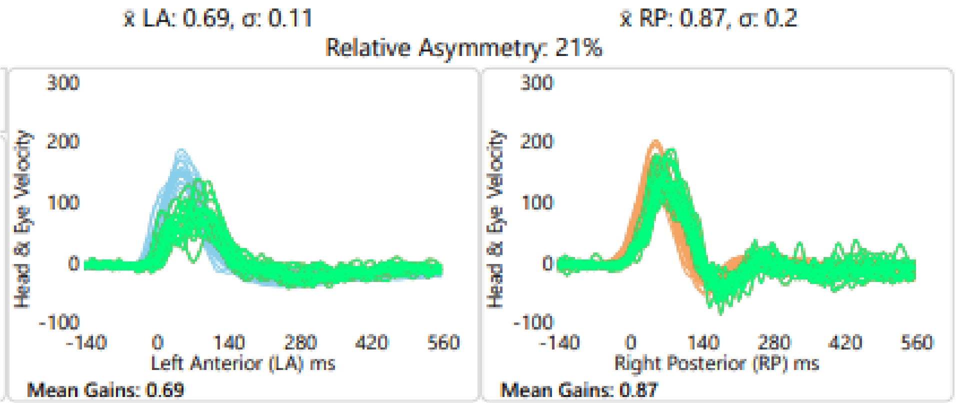


Figure 4.5 *Mean VOR gain of LARP plane in one of the individuals with Mixed Hearing loss*

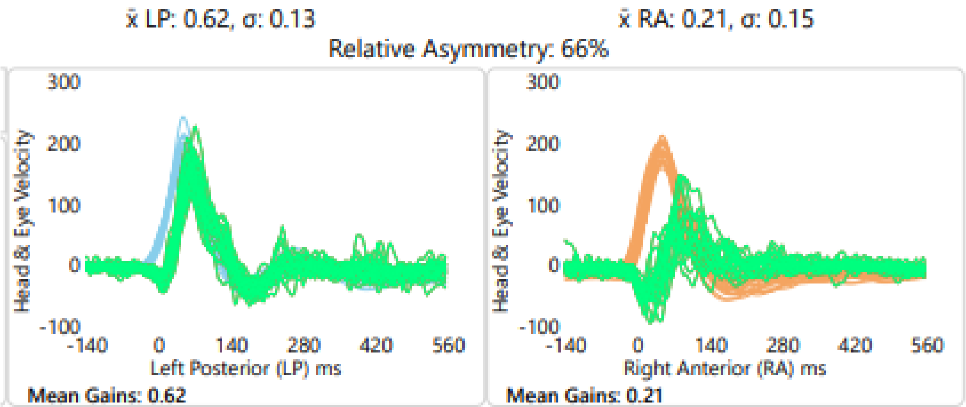


Figure 4.6 *Mean VOR gain of RALP planes in one of the individuals with Mixed Hearing loss*

The data was subjected to Shapiro-Wilk test to check whether it follows normal distribution or not. The test results showed that the data followed a normal distribution (*p*>0.05), and hence parametric tests was performed to compare the mean VOR gain between normal and mixed hearing loss group. Descriptive statistics was done to calculate the mean and standard deviation (SD) of VOR gain for both the groups. The mean VOR gain was calculated for each of the semicircular canal separately for both the groups and is given in Table 4.1.

Table 4.1 *Mean VOR gain and Standard Deviation (SD) of Normal Hearing individuals and individuals with Mixed Hearing loss*

Group	**N**	**Plane**		**Mean**	**SD**
Normal Hearing	15	Lateral	L-lateral-meanVORgain	0.95	0.08
			R-lateral-meanVORgain	1.08	0.10
		RALP	R-anterior-meanVORgain	0.81	0.10
			L-posterior-meanVORgain	0.75	0.13
		LARP	L-anterior-meanVORgain	0.86	0.11
			R-posterior-meanVORgain	0.76	0.14
Mixed hearing loss	15	Lateral	L-lateral-meanVORgain	1.04	0.15
			R-lateral-meanVORgain	1.09	0.15
		RALP	R-anterior-meanVORgain	0.65	0.19
			L-posterior-meanVORgain	0.75	0.12
		LARP	L-anterior-meanVORgain	0.78	0.13
			R-posterior-meanVORgain	0.96	0.20

Note. R= Right; L=left; VOR= vestibule-occular reflex

From Table 4.1, it can be noticed that the mean VOR gain of the left anterior canal in the LARP plane and right anterior canal in the RALP plane in mixed hearing individuals is lesser than the control group. The mean VOR gain of left and right lateral canal in lateral plane in mixed hearing individuals are comparatively higher than the control group. Similarly, mean VOR gain of the right posterior canal in LARP plane and left posterior canal in the RALP plane are comparatively higher in the mixed hearing individuals than the control group. The same can be seen in Figure 4.7

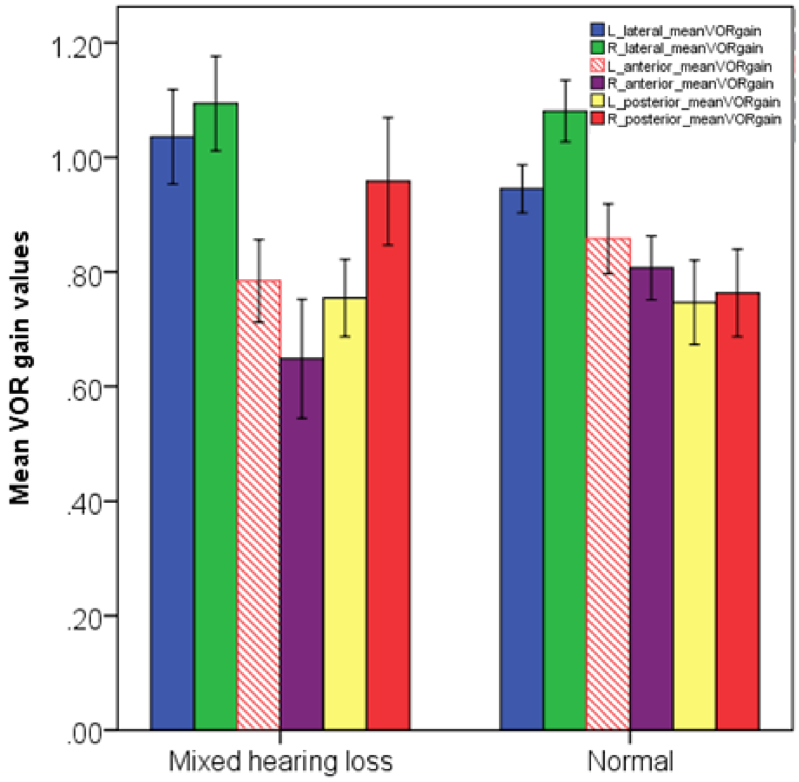


Figure 4.7 *Mean VOR gain of all six semicircular canals in individuals with Mixed Hearing loss and Normal Hearing.*

Further, to investigate the significant difference between the groups for the mean VOR gain, Multiple analysis of Variance (MANOVA) was performed. MANOVA results showed no significant main effect between the groups in VOR gain of right lateral [F (1, 28) = 0.08, p>0.05], left anterior [F (1, 28) = 2.83, p>0.05] and left posterior [F (1, 28) = 0.03, p>0.05]. Whereas MANOVA showed a significant main effect in VOR gain between the groups of left lateral [F (1, 28) = 4.42, p<0.05], right anterior [F (1, 28) = 8.32, p<0.05] and right posterior [F (1, 28) = 9.59, p<0.05].

Since there were only two groups, an independent sample t-test was also performed to compare the mean VOR gain between the groups. Results showed no significant difference between the groups for mean VOR gain of right lateral [t (28)= 0.29, p>0.05], left anterior [t (28)= 1.68, $p>0.05$] and left posterior [t (28)= -0.17, $p>0.05$]. However, a significant difference was noted between the groups for VOR gain of left lateral [t (28)= 2.10, $p<0.05$], right anterior [t (28)= 2.88, $p<0.05$] and right posterior [t (28)= 3.10, $p<0.05$].

In summary, based on the statistical tests performed, the mean VOR gain of the left lateral, right anterior and right posterior of the mixed hearing individuals were significantly higher than the normal hearing individuals whereas the right anterior was considerably lower in mixed hearing individuals.

4.2 Subjective visual vertical results in individuals with normal hearing and individuals with mixed hearing loss

Average Ocular tilt of 5 trials measured for 0 degree, 30 degree right, and 30 degree left head tilt for all participants in group I and group II. Representative figure of ocular tilt at 0 degree and 30 degree head tilt to both sides are given in the figure 4.8 and 4.9 for normal hearing individuals and individuals with mixed hearing, respectively.

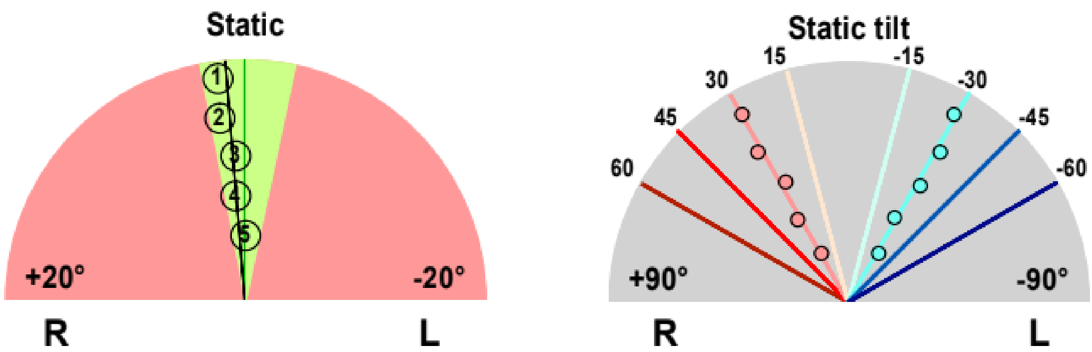


Figure 4.8 *Representative report of ocular tilt at 0 degree and 30 degree head tilt to both the sides of an individual with Normal Hearing*

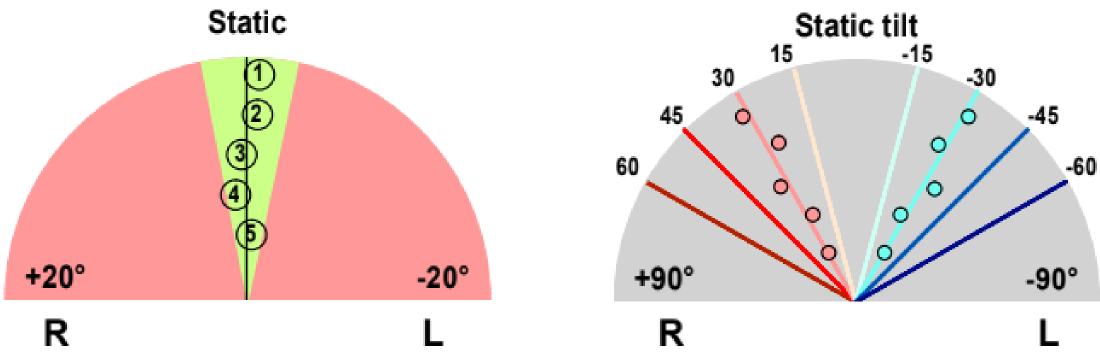


Figure 4.9 *Representative report of occular tilt at 0 degree and 30 degree head tilt to both the sides of an individual with Mixed Hearing loss.*

The data was subjected to Shapiro-Wilk test to check for normality. The test results showed that the data did not follow a normal distribution (p <0.05). Hence, non-parametric tests was performed to compare the mean ocular tilt between normal and mixed hearing loss groups. Descriptive statistics was done to calculate the mean and standard deviation (SD) of occular tilt for both groups. The group average of ocular tilt was calculated for all three head positions separately for both the groups and is given in Table 4.2.

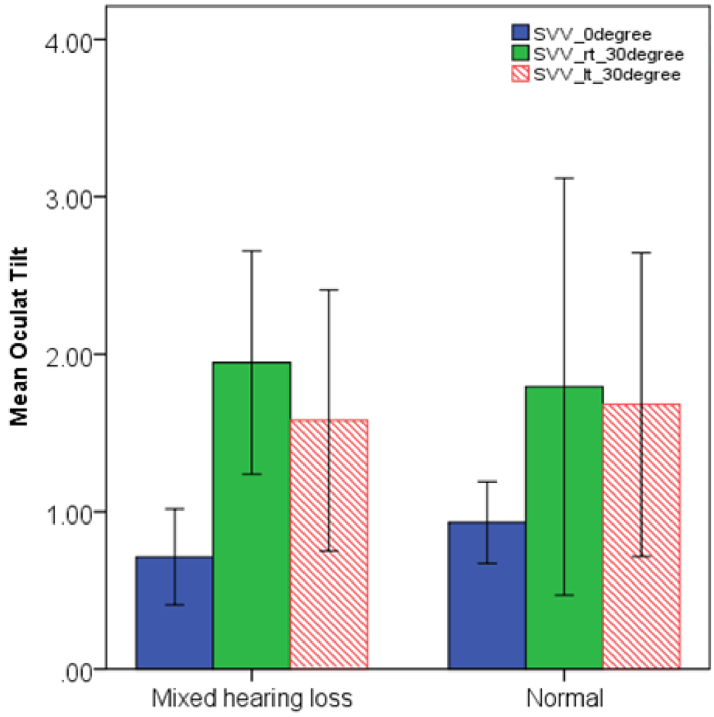
Table 4.2 *Mean ocular tilt and standard deviation (SD) of Normal Hearing individuals and individuals with Mixed Hearing loss at three static head positions.*

Group	N		Mean	SD
Normal Hearing	15	SVV_0degree	0.93	0.47
		SVV_R_30degree	1.79	2.39
		SVV_L_30degree	1.68	1.74
Mixed hearing loss	15	SVV_0degree	0.71	0.55
		SVV_R_30degree	1.94	1.28
		SVV_L_30degree	1.58	1.50

Note. R= right; L= left;

It can be seen from the Table 4.2 that the ocular tilt of the mixed hearing group is better than the control group at static head position (0 degree head tilt) and 30-degree head tilt to the left. Whereas the ocular tilt of the mixed hearing group is weaker than the control group than the control group at 30 degree head tilt to right side. The same can be seen in Figure 4.10

Figure 4.10 *Mean ocular tilt of Normal Hearing individuals and individuals with Mixed Hearing loss at three static head positions.*



Further, to investigate the significant difference between the groups for the mean ocular tilt, Mann-Whitney U-test (non-parametric test) was performed to compare the mean ocular tilt between the groups. The results revealed no significant statistical difference between the two groups at 0 degree (z= 1.19; *p*= 0.23), 30 degree tilt to right (z= -1.9; *p*= 0.16) and 30 degree tilt to left (z= 0.00; *p*= 1.00)

To summarise, based on the Mann-Whitney U test, there was no significant difference in the occular tilt in SVV at any of the static head positions between the mixed hearing loss group with respect to the control group.

4.3 Correlation between SVV and VOR gain in Normal Hearing individuals

Mean VOR gain of v-HIT was correlated with various static head positions (0 degree, 30 degree right, 30 degree left) of SVV in normal group. Spearman's correlation test revealed no correlation between various parameters of v-HIT and different head positions of SVV (p>0.05).

4.4 Correlation between SVV and VOR gain in individuals with Mixed Hearing loss

Mean VOR gain of v-HIT was correlated with various static head positions (0 degree, 30 degree right, 30 degree left) of SVV in mixed hearing loss group. Spearman's correlation test revealed no correlation between various parameters of v-HIT and different head positions of SVV (p>0.05).

To summarise, the mean VOR gain of the left lateral, right anterior and right posterior of the mixed hearing individuals were significantly higher than the normal hearing individuals, whereas the VOR gain for right anterior was considerably lower in mixed hearing individuals. However, there was no significant difference in the ocular tilt in SVV at any of the three static head positions between the mixed hearing loss group with respect to the control group.

Chapter- V

Discussion

In the present study, the mean VOR gain of the left lateral, right anterior and right posterior of the mixed hearing individuals were significantly higher than the normal hearing individuals whereas the right anterior was considerably lower in mixed hearing individuals.

There is a dearth of information regarding the VOR gain in individuals with mixed hearing loss. Some of the studies hae utilised other test to assss the VOR gain functions in individuals with mixed hearing loss or conductive hearing loss. Paparella et al . (1979) recorded air caloric test results in patients with unilateral otitis media with tubes or a slight perforation of one ear that can display a caloric response equal to the intact side. Whereas on the perforated side of a large perforations can display a hyperactive caloric reaction. But a moist ear (with either a large perforation) may display an inverted horizontal nystagmus to warm caloric stimulation of the air; and dry open mastoid or fenestration cavities are more likely to show hyperactive caloric responses.

Casselbrant et al. (1995) conducted vestibular tests with a moving-platform posturography on fourty-one children with otitis media before and after insertion of a ventilation tube. They observed a substantial increase in sway among the children with otitis media compared to controls.

Kaźmierczak et al. (2003) studied sixty adult patients with chronic otitis media with ENG and stabilometric analysis and reported that dysfunction of the inner ear was mostly seen in subjects with cholesteatoma.

Engel-Yeger et al. (2004) studied twenty children with Middle ear effusion (MEE) and twenty controls with ENG and balance and strength sub-tests of Bruininks-Oseretsky Test of Motor Performance (BOTMP). Although both the groups did not show any abnormalities on ENGThe MEE group showed significantly lower results on the BOTMP balance subtest in comparison to the control group.

Gianoli and Soileau (2008) reported a high incidence of Caloric abnormalities (76%) and Rotational chair testing (72%) in a group of patients with CSOM. They also reported that the high degree of accuracy (80%) of caloric testing to predict Rotational chair testing abnormalities which supports the validity of caloric testing in individuals with conductive hearing loss.

Ho et al. (2012) reported a high incidence (81.1%) of abnormality in results of either caloric test or VEMP test in patients with unilateral simple Chronic Otitis Media.

Mostafa rt al. (2013) studied vestibular functions in patients with chronic suppurative otitis media (CSOM) with and without sensori-neural hearing loss and reported that the vestibular system is remarkably affected in subjects with CSOM. They also reported incidence of 70% of Rotatory chair abnormalities, 61.6% of caloric hypo-function, and 25% abnormality of vestibular myogenic evoked potentials. They observed that both semicircular canals as well as the saccule are affected by the CSOM and hence all patients with long-standing CSOM should undergo vestibular evaluation irrespective of their hearing levels.

A study done by D’Albora et al. (2017) demonstrated three patients with radiologically and surgically confirmed horizontal semicircular canal fistula but with a false negative fistula test showed an abnormal vestibule-ocular reflex in Bedside head impulse testing using the vHIT and in one case was they were also able to localize the deterioration to a particular semicircular canal.

Covelli et al. (2019) reported a reduced VOR gain and catch-up saccades thirty days post surgery of cholesteatoma complicated by fistula of lateral semicircular canal; normalized VOR gain six months and one year post surgery. They also reported that, the

VOR gain in the nonaffected side generally experienced an increase, paralleled by the normalization on the affected side. However, the subjects with normal v-HIT before surgery did not show any variation following surgery.

However, on the other hand, other studies show there is no much effect on the vestibular system in individuals with conductive deficits. Ben-David et al. (1993) reported on the outcome of vestibular testing in fifty children with middle ear effusions who were scheduled for placement of ventilation tube compared to twenty control subjects. They found no difference between the two groups in results of craniocorpography and rotatory chair testing preoperative and postoperative.

"*In the present study, it was also observed that out of fifteen participants in the Mixed Hearing Loss group, nine participants had a presence of refixation saccades.*

The presence of refixation saccade is a pathological response (eyes move opposite to the head movement but after a delay) because the eyes no longer compensate for the head movement" (Weber et al., 2009*).* Perez-Fernandez and Eza-Nuñez (2015) reported few patients with vestibular pathology who presented with a normal VOR gain and presence of refixation saccades, which could be a sign that some degree of damage must have been persisting in the side in which the impulse generates a normal value gain with refixation saccades.

In the present study, the VOR gain was higher for few participants with mixed hearing loss in a few of the canals, whereas; the VOR gain was lesser for few canals in individuals with mixed hearing loss.

The VOR gain findings in the present study do not provide conclusive results, and further studies are required to explore the VOR gain findings in individuals with mixed hearing loss. However, the presence of saccades in individuals with mixed hearing loss indicate a presence of peripheral pathology in individuals with mixed hearing loss.

It was noted in the present study that there was no significant difference in the mean occular tilt at any of the three static head position between the groups.

Lee et al. (2009) reported incidence of 48% pathologic head shake nystagmus, 28% pathologic vibration-induced nystagmus, and 20% pathologic SVV in vestibular function tests (VFT) done on patients with unilateral chronic otitis media. Overall 80% patients showed abnormal findings through a set of VFTs.

In a study done by da Costa Monsanto et al. (2020) reported that the patients with CSOM (with and without cholesteatoma) had significantly higher deviations (CSOM= 3.66 degree)of the true vertical when compared to controls (controls= 0.76 degree)

Tabak et al. (1997) measured SVV in thirty two subjects with long standing unilateral vestibular loss, seven subjects with partial unilateral vestibular loss and eight subjects with bilateral vestibular loss. They reported that The mean occular tilt in subjects with clinically bilateral vestibular loss (-1.17 degrees + 1.96) did not significantly differ from the control group.

Guerraz et al. (2001) evaluated SVV in complete darkness (i.e. no frame, no disc), during the static visual disturbance (frametilted by 28 degrees) and kinetic disturbance (disc rotating at 30 degrees/s) in Sixteen bilateral thelabyrinthine-defective subjects and reported that there was no difference between the groups when SVV was performed in darkness. However they also reported that occular tilt of SVV was more in bilateral thelabyrinthine-defective subjects during static frame tilt and disc rotation.

Lopez et al. (2007) conducted a study on fourty Menière disease subjects before and after (from one week to one year) a curative unilateral vestibular neurotomy (UVN) and four bilateral vestibular loss patients to see the effect of unilateral and bilateral vestibular deafferentation on visual vertical perception in the presence of dynamic and static visual cue.They observed a grater impairment of dynamic visual vertical in

Menière's patients in the acute stage after UVN and it was tilted towards the pathologic side irrespective of the direction of the optokinetic stimulation. In addition, the SVV was systematically tilted towards the lesioned side. They also reported The regaining of SVV to normal values one year postoperatively. However, the optokinetic-induced tilt of the visual vertical was significantly increased in patients with bilateral vestibular impairment, and symmetrically arranged around an unmodified SVV aligned with the gravitational vertical.

Funabashi et al. (2012) evaluated subjective visual vertical in patients with bilateral vestibular dysfunction (BVD) and reported that the SVV in subjects with bilateral vestibular damage were indistinguishable from the SVV in healthy countrpart when calculated using conventional technique which suggest that patients with BVD exhibit a larger range of variations in SVV compared to the range exhibited by control subjects. But when absolute values and ranges of the absolute SVV values were considered, subjects with bilateral vestibular dysfunction presented a significantly higher range of SVV tilts compared to control group.

Various studies are showing that the many conductive pathology can have an impact on the vestibular function tests in individuals with conductive or mixed hearing loss which might be related to the gradual vestibular involvement in inflammatory processes. Considering the high incidence of vestibular test abnormalities in this population, more research has to be done to explore the possible impairments in vestibular system due to a conductive pathology. Based on the results of previous studies, it appears that a long standing or bilateral vestibular involvement can result in large variations in occular tilts of SVV.

Chapter- VI

Summary and Conclusion

The SVV is a method to test an individual's ability to adjust a vertical line to be parallel with gravity in the absence of other visual cues, perception of verticality. The sensory information required to perform this task is provided predominantly by the vestibular organs of the inner ear, and, in particular, by the utricles.

Hence the present study was aimed to assess the functioning of the utricle and semicircular canals and its associated pathway using video head impulse test (v-HIT) and subjective visual vertical (SVV) in individuals with mixed hearing loss. The objective of the study was to study the functioning of utricle and semicircular canals in individuals with mixed hearing loss using Subjective visual vertical (SVV) and Video head impulse test (v-HIT).

To achieve the aim of the study, 15 individuals with unilateral or bilateral mixed hearing loss were evaluated using SVV and vHIT, and the results were compared with the results of 15 normal-hearing individuals. All the participants underwent a routine hearing evaluation which included detailed case history, pure tone audiometry and Immittance audiometry. For v-HIT testing, vestibuloocular reflex gain (VOR gain) and the presence of any refixation saccades were measured. For SVV, average ocular tilt for 0degree and 30-degree static head tilt on either side was measured.

- Descriptive statistics was done to calculate the mean and standard deviation (SD) of VOR gain of all six semicircular canals and ocular tilt at three different static head positions for both the groups.
- The data were subjected to the Shapiro-Wilk test to check the normality.

- ❖ Independent sample t test and MANOVA was performed to compare the mean VOR gain of all six semicircular canal in v-HIT between the mixed hearing and normal hearing group.
- ❖ Mann-Whitney U-test was performed to compare the mean occular tilt at all three head positions of SVV between the mixed hearing and normal hearing group.
- ❖ Spearman's correlation test was performed to find a correlation between the results of SVV and v-HIT.

The results of the above mentioned statistical tests are as follows,

1. *Video head impulse test*

- ❖ There was no statistically significant difference in the mean VOR gain of the mixed hearing individuals in the right lateral, left anterior and left posterior semicircular canal when compared to the normal group.
- ❖ A significant difference was noted between the groups in for VOR gain of left lateral, right anterior and right posterior semicircular canals.

2. *Subjective visual vertical test*

- ❖ There was no statistical difference in the mean occular tilt at all three static head positions between the groups.

Conclusions

SVV and v-HIT together can provide information about the functioning of utricle and the semicircular canal. Due to the technical disadvantage of VEMP and Caloric testing, assessing the functioning of the vestibular system in mixed hearing individuals is challenging. SVV and v-HIT together is a good tool in assessing and diagnosing vestibular dysfunction in mixed hearing individuals. The present study revealed dysfunction of few semicircualr canal in mixed hearing loss individuals. However, the SVV findings were within the normal limits in both the groups. Further studies are required to understand the clinical applicability of SVV and vHIT in individals with mixed hearing loss.

Implications of the study

The study provides knowledge about the functioning of utricle and semicircular canals in individuals with mixed hearing loss. The study provides an insight into the need for assessment of vestibular functioning in individuals with mixed hearing loss.

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