ASSESSMENT OF OTOLITH ORGANS AND SEMICIRCULAR CANALS FUNCTIONS IN INDIVIDUALS WITH DIABETES MELLITUS

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This Dissertation is submitted as a part-fulfillment

For the Degree of Master of Science in Audiology

University of Mysore, Mysore

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May 2019

CERTIFICATE

This is to certify that this dissertation entitled **'Assessment Of Otolith Organs And Semicircular Canals Functions In Individuals With Diabetes Mellitus'** is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No: **17AUD027**. 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.

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May 2019

DECLARATION

This is to certify that this Master's dissertation entitled **'Assessment Of Otolith Organs And Semicircular Canals Functions In Individuals With Diabetes Mellitus'** is the result of my own study under the guidance of Dr. Sujeet Kumar Sinha, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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Abstract

Aim: The study was designed to assess the functioning of saccule, utricle and all six semicircular canals in individuals with diabetes mellitus.

Method: Group one consisted of 28 diabetic participants and 28 non diabetic participants in the age range of 35-65 years were involved in the study. All the participants evaluated based on detailed case history, pure tone audiometry, immittance audiometry, oVEMP, cVEMP, and vHIT tests.

Results: cVEMP was present in 80.3% non diabetic individuals and in 51.78% diabetic individuals. There was no significant difference in the latencies of p1 & n1 in non diabetic and diabetic individuals. However, the significant difference was seen in the p1n1 amplitude complex of non diabetic individuals and diabetic individuals. oVEMP was present in 58.91% of non diabetic individuals and 33.92% of diabetic individuals. There was no significant difference found in the latencies of n1, p1 & n2 in non diabetic and diabetic individuals. Also there was no significant difference in the p1n1 & p1n2 amplitude complex in non diabetic and diabetic individuals. In vHIT, there was no significant difference in VOR gain and asymmetry ratio of all the six semicircular canals of non-diabetic and diabetic individuals. However, the significant difference was noted in the asymmetry ratio of VOR gain in left anterior-right posterior plane of non diabetic and diabetic individuals.

Conclusions: cVEMP and oVEMP along with vHIT provide detailed information about saccule, utricle and semicircular canals. Hence, these tests can be used to assess functioning of vestibular structures in different vestibular pathologies. The VOR gain asymmetry ratio was more in Diabetes individuals which could be suggestive of some abnormality between right and the left vestibular system. It is recommended to assess the vestibular system in all the individuals with diabetes.

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Chapter I

INTRODUCTION

Three sensory systems play a vital role in balancing the body 1. Proprioceptive system 2.Vestibular system and 3.visual system. The vestibular system mainly involves five sensory organs in each side of the ear which includes three semicircular canals and two otolith organs. These sensory organs are filled with endolymphatic fluid which is rich in sensory hair cells. These organs are helpful in recognizing the head movements and balancing the body along with Proprioceptive and visual cues. Damage to the vestibular system or any pathology related to the vestibular system, can create problems related to the balance of the body.

Diabetes mellitus is one of the most common chronic metabolic disorders occurring across the world. India ranked highest in the world in 2000 with 31.7 million individuals having diabetes mellitus, whereas China (20.8 million) was on second place followed by United States (17.7 million). D'Silva, Lin, Staecker, Whitney, and Kluding (2016) reported that diabetes mellitus is considered as one of the causes which have raised the risk of falls and dysfunction of the vestibular system. Thus, individuals with diabetes require vestibular assessment. Different tests are utilised for assessment of different parts of the vestibular system. For the assessment of saccule and its innervating structure cVEMP is utilised, for the assessment of utricle and its innervating structures oVEMP is utilised and for the assessment of semicircular canals vHIT is utilised.

Cervical vestibular evoked myogenic potentials (cVEMP) are generated from sternocleidomastoid muscle by giving high level acoustic stimuli. It is one of the accepted tests to measure functioning of saccule and inferior vestibular nerve (Papathanasiou, Murofushi, Akin, & Colebatch, 2014). Cervical vestibular evoked myogenic potentials has been helpful in diagnosing number of disorders such as

vestibular neuritis (Murofushi, T., Halmagyi, Yavor, & Colebatch, 1996), Acoustic Neuroma (Murofushi, Matsuzaki, & Mizuno, 1998), Meniere's disease (Kim-Lee, Ahn, Kim, & Yoon, 2009), Vestibular migraine (Furman, & Balaban, 2015), and Superior semicircular canal dehiscence (Hunter, 2017).

Ocular vestibular evoked myogenic potentials test is used to assess utricular functioning via superior vestibular nerve. It is a biphasic waveform which is generated from the contralateral inferior oblique muscle (Fife et al., 2017). Ocular vestibular evoked potentials are utilized in diagnosing various vestibular disorders such as Superior semicircular canal dehiscence (Zuniga, Janky, Nguyen, Welgampola, & Carey, 2013), Benign paroxysmal positional vertigo (Singh & Apeksha, 2016), Meniere's disease (Huang, Wang, & Young, 2011), Vestibular neuritis (Govender, Dennis, & Colebatch, 2015), Multiple sclerosis (Gazioglu & Boz, 2012), and Auditory neuropathy spectrum disorder (Sinha, Shankar, & Sharanya, 2013).

Video head impulse test allows testing vestibular functions of all the semicircular canals individually by measuring eye rotation response to a sudden head rotation response in the plane of that particular canal (McGarvie et al., 2015). Video head impulse test is useful in the diagnosis of various vestibular disorders such as Vestibular neuritis (MacDougall, Weber, McGarvie, Halmagyi&Curthoys, 2009), Meniere's disease (Blödow, Pannasch, & Walther, 2013), and also to diagnose balance disorders in childhood includes benign paroxysmal positional vertigo, vestibular migraine and post traumatic vertigo (Sommerfleck, et al., 2016).

1.1 NEED OF THE STUDY

1.1.1. Need of vestibular studies in Diabetes Mellitus

Diabetes mellitus is a chronic metabolic disorder which occurs due to an inability of the human body to produce insulin, resist insulin action or both (American Diabetes Association in 2009; D'Silva et al., 2016). D'Silva et al., (2016) reported structural and morphological changes in the peripheral vestibular system of diabetic animals, which increases the amount of extracellular matrix, lysosomes and lipid droplets in the connective type of tissues in utricle and saccule. The overproduction of extracellular matrix and lipid droplets causes inability to diffuse oxygen molecules, waste product and nutrients. Also it leads to degeneration of type-1 hair cells in both utricle and saccule (D'Silva et al., 2016). Saccule is found to be more susceptible to diabetes mellitus.

Kocdor, Kaya, Erdil, Cureoglu, Paparella and Adams (2016) reported that, compared to normal individuals, individuals with diabetes mellitus have a lower density of type 1 vestibular hair cells in the saccule. Agrawal, Carey, Della Santina, Schubert and Minor (2010) found significant growth in the prevalence of vestibular dysfunction because of longer duration and higher amount of hemoglobinA1c levels in individuals with diabetes mellitus. Authors concluded that vestibular dysfunction as a newly identified complication of diabetes mellitus. Although there are many anatomical and physiological studies related to changes in the vestibular system of individuals with diabetes, however, there is a dearth of information on evaluation of the vestibular system in individuals with diabetes mellitus; hence, there is a need to study the vestibular system functions in Individuals with diabetes mellitus.

1.1.2. Need of vestibular evoked myogenic potentials studies in Diabetes Mellitus

Various studies have shown the importance of vestibular myogenic potential (VEMP) in diagnosing various pathologies such as, Meniere's disease

(MD)/endolymphatichydrops, Vestibular Migraine (VM), Semicircular canal dehiscence (SCD), vestibular neuritis (VN), Rheumatoid arthritis, etc. Lamounier, de Souza, Gobbo, and Bahmad (2017) found the specificity and sensitivity of both vestibular evoked myogenic potentials (VEMP) and electrocochleography (EcochG) in individuals with Meniere's disease. Results of their study showed that, the specificity was high for both the tests but the sensitivity of VEMP was higher than EcochG in the Meniere's disease.

Salviz, Yuce, Acar, Taylan, Yucent, and Karatas (2015) concluded that, the latencies of P13 and N23 were similar to any healthy participants in the control group although, peak to peak amplitude was reduced bilaterally at 500 TB (Tone burst) in individuals with Meniere's disease. Authors also concluded that the cVEMP can be used as a diagnostic tool to differentiate Meniere's disease from a vestibular migraine. Bremova, Caushaj, Ertl, Strobl, Bottcher, Strupp and MacNeilage (2016) measured the linear motion perception thresholds by using cVEMP and oVEMP recording and found out high linear motion perception thresholds in Meniere's disease as compared to a vestibular migraine and healthy control group.

Semicircular canal dehiscence is not a very common type of disorder in which the bone which covers the superior semicircular canal will become thin or dehisces and generates symptoms such as vertigo & bone conduction hyperacusis (Ward, et al. 2013). Crane, Carey and Minor (2010) found out that 80% of sensitivity and 80% of specificity of decreased click-evoked thresholds in individuals with semicircular canal dehiscence.

The study done by Sheykholeslami, Kaga, Murofushi and Hughes (2000) based on VEMP findings reported that, isolated auditory neuropathy might affect the vestibular branch of VIIIth cranial nerve in suffered individuals. Also it can create a balance problem. In individuals with isolated auditory neuropathy which also might affect the vestibular branch of VIIIth cranial nerve and can create balance problem. Various studies

have shown that diabetes mellitus can cause structural and physiological changes in the inner ear. A lot of changes have been noticed prominently in the cochlea as compared to the vestibular system. There are very few studies which have reported VEMP findings in individuals with diabetes mellitus.

Ward et al. (2015) reported that around 50% of individuals with diabetes mellitus showed impairment of otolith organ whereas 70% have shown dysfunction of at least 1 semicircular canal. Bektas, Gazioglu ,Arslan ,Cobanoglu, Boz and Caylan (2008) reported that VEMP responses are not affected by non-insulin-dependent diabetes mellitus patients with and without polyneuropathy. Kalkan, Bayram, Gokay, Kura and Mutlu (2018) recorded cVEMP and oVEMP, results have shown that there was no significant difference between the recordings of right and left ear in patients with diabetes mellitus/polyneuropathy and control group. However, the significant difference was observed in the amplitude of cVEMP. The amplitude got reduced in individuals with diabetes mellitus/polyneuropathy when they compared with the healthy control group. Thus, there are equivocal findings in vestibular evoked myogenic potentials in individuals with diabetes mellitus and hence there is a need to study the vestibular evoked myogenic potentials in individuals with diabetes mellitus.

1.1.3. Need to study v-HIT in Diabetes Mellitus

In comparison to caloric test which assesses only the lateral semicircular canals, vHIT is considered the better alternative which assesses all the six semicircular canals. vHIT measures the vestibular ocular reflex (VOR). A study done by Yacovino and Finlay (2016) showed temporary change in VOR during the Menier's attack. According to Constanzo, Sens, Teixeira and Ramina (2019) vHIT can also be used in the preoperative identification of the origin of the nerve of vestibular schwannoma. From

their study authors concluded that, nearly in 87% of cases vHIT was able to identify the origin of a nerve of vestibular schwannoma correctly.

There is a dearth of information on vHIT test findings in individuals with diabetes mellitus. Thus there is a need to assess all semicircular canals in individuals with diabetes mellitus.

1.2 Aim of the study

The aim of the study was to assess the functioning of saccule, utricle and all six semicircular canals in individuals with diabetes mellitus.

1.3 Objectives of the study

1. To study the functioning of utricle in individuals with diabetes mellitus.
2. To evaluate the functioning of saccule in individuals with diabetes mellitus.
3. To assess the functioning of six semicircular canals in individuals with diabetes mellitus.
4. To correlate the test findings of VEMP parameters and vHIT with duration of diabetes mellitus.
5. To check association between VEMP and degree of hearing loss in individuals with diabetes mellitus.

Chapter II

REVIEW OF LITERATURE

The inner ear consists of hearing system and vestibular system. Cochlea is responsible for hearing and otolith organs and semicircular canals are important for balancing the body. This hearing system and vestibular system are connected anatomically. The incidence of diabetes mellitus is increasing all over the world with an estimated value of 382 million populations (Ibraheem, Hussaan&Mousa, 2017). Diabetes mellitus is a metabolic disorder of glucose mechanism and it can also involve dysfunctioning of vestibular system (Rybak 1995). Vestibular dysfunction associated with risk of falls and impaired balance (D'Silva et al., 2015).

Authors found that vertigo and dizziness seen in diabetes mellitus patients can be associated with vestibular dysfunction (Li et al., 2008). Diabetic adults showed poorer performance on vestibular function tests to assess semicircular canals and otolith organs when compared to age matched adults (Ward et al., 2015). There are metabolic disturbances seen in type 1 diabetes mellitus patients which can lead to disturbances in auditory and balance system (Mohammad, Robabeh, Shahin, Saeed& Maryam, 2018). Authors hypothesized that, there is a direct connection between chronic hyperinsulinemic/hyperglycaemic damage and peripheral vestibular system (Gioacchini et al., 2018). Authors reported that diabetes related complications acts as a mediator of diabetes mellitus effects on the risk of fall (Agrawal at al., 2010).

2.1. Applications of vestibular evoked myogenic potentials in various vestibular disorders

2.1.1. *Meniere's disease*

Kuo, Yang and Young (2005) recorded VEMP and Videonystagmography (VNG) from12 patients with Meniere's disease. Authors found that in the beginning of Meniere's attack the spontaneous nystagmus was beating on the same side of lesion in 5 individuals whereas; on the opposite side of lesion in 7 individuals. VEMP was recorded within 24 hours of attack and showed abnormal VEMP in 8 patients and normal findings in 4 patients. After 48 hours, 4 patients with initially abnormal VEMPs had resolution and return to normal VEMPs, and the other 4 patients still had absent VEMPs. Authors concluded that saccule is involved in a Meniere's attack.

Akkuzu, Akkuzu and Ozluoglu (2006) recorded VEMP in patients with Meniere's disease and benign paroxysmal vertigo. Total 62 individuals were involved in this study. Among 62 participants 17 healthy controls, 20 participants with Meniere's disease and 25 with benign paroxysmal vertigo were included in the study. Out of 20 ears affected in Meniere's disease, four ears showed absent VEMP and six ears showed prolonged latencies. Further authors stated that rate of abnormal VEMP recording was more in both the groups as compared with control group.

Johnson et al. (2016) evaluated 18 patients with certain Meniere's disease and 22 normal volunteers based on cVEMP and oVEMP. Authors stated no significant difference in thresholds of cVEMP between Meniere's disease patients and control group but oVEMP showed elevated thresholds in patients with Meniere's disease as compared to control group. N1 latencies of cVEMP were prolonged when compared with normal ears individuals but not with non affected ear. Further authors found that in cVEMP P1N1 and N1P2 amplitude were reduced when compared to right ear of control group, but not with non-affected ear whereas; in oVEMP N2P2 amplitudes were significantly reduced compared with both ears of controls but not with the non-affected ear. Authors concluded that there was a significant overlap in oVEMP results of normal individuals

and individuals with Meniere's disease. Hence VEMP cannot be used as a sole criterion to diagnose Meniere's disease.

Lamounier et al. (2017) evaluated the sensitivity of VEMP and Electrocochleography in the diagnosis of Meniere's disease. Authors included total 24 individuals. 12 were diagnosed as definite Meniere's disease whereas other 12 were normal individuals as a control group. In this study all individuals underwent otoneurological evaluation including pure tone, speech audiometry, VEMP and extratympanicelectrocochleography. They calculated the sensitivity and specificity to detect the presence or absence of Meniere's disease. The results of their study indicated that VEMP got more than 63% of sensitivity for both ears whereas Extratympanic EcochG got 63.6 % of sensitivity in the right ear and 37.5% for the left ear to detect the disease. They concluded that specificity for both tests were high and sensitivity for VEMP was higher than the EcochG.

2.1.2. Vestibular Neuritis

Zhang et al. (2010) analyzed cVEMP in 216 patients retrospectively. All the patients were evaluated based on systematic investigation, including hearing evaluation, radiology, caloric testing and vestibular assessment. Authors found that out of 216 patients, eight patients were diagnosed as inferior vestibular neuritis. In six cases showed unilateral loss of vestibular evoked myogenic potentials, whereas two patients had unilateral reduced amplitude.

Shin et al. (2012) recorded cVEMP and oVEMP in patients with vestibular neuritis. The study included 60 normal individuals and 41 patients with acute vestibular neuritis. Among 41 patients, 30 with superior vestibular nerve involvement, 3 with involvement of inferior vestibular nerve and 8 patients with involvement of both superior and inferior vestibular nerve were involved in the study. Authors found that cVEMP was

normal in patients with superior vestibular neuritis however, oVEMP was absent in all patients with superior nerve involvement. In contrast oVEMP was normal and cVEMP was abnormal in patients with inferior vestibular neuritis.

Walther et al. (2013) evaluated cVEMP& oVEMP in response to 500 Hz air conduction stimulation and compared these results with video head impulse test (vHIT) simultaneously. In results authors found that, cVEMP& oVEMP in combination with video head impulse test gives better differentiation of four types of vestibular neuritis i.e. inferior vestibular neuritis, superior vestibular neuritis, entire vestibular neuritis and ampullary vestibular neuritis and lesions can be complete or partial. Further they concluded that different origin of air conduction oVEMP and air conduction cVEMP to 500 Hz in complete superior vestibular neuritis and inferior vestibular neuritis. Partial superior vestibular neuritis and inferior vestibular neuritis may indicate a role of saccularfibers in oVEMP.

2.1.3. Benign Paroxysmal Positional Vertigo

Boleas-Aguirre et al. (2007) recorded VEMP in 19 individuals with posterior canal benign paroxysmal positional vertigo (BPPV). All patients were evaluated on their auditory function and their caloric, rotatory chair, and VEMP tests. Ipsilateral and contralateral VEMP thresholds, ipsilateral and contralateral P1 and N1 latencies by presenting the stimulus at 100dB, inter-peak amplitude, and inter-aural amplitude difference were measured in all subjects. In results authors stated that, VEMP was absent in 52% of the ears with BPPV. And When adjusted for bilateral absence, VEMP response was absent in 20.3% of ears. Conclusion made by the authors was in some patients having BPPV with idiopathic cause might have some degree of saccular dysfunction.

Korres et al. (2011) studied VEMP in 27 individuals with Benign Paroxysmal Positional Vertigo (BPPV) and 30 healthy age matched individuals in control group between 20-70 years. All subjects were evaluated on pure tone audiometry, with electronystagmography (ENG) recording, bi-thermal caloric test, and VEMP recording. Authors found that the percentage of abnormal VEMP was high in BPPV ears than the control group ears but there was no significant difference was seen in latency of peak N1 & peak P1 between the two groups. Authors could not see any significant relationship between the occurrence of canal paresis and abnormal VEMP. BPPV is a clinical entity associated with increased occurrence of abnormal VEMP recordings, possibly due to degeneration of the saccular macula, which is part of the neural VEMP pathway.

Yetiser et al. (2014) administered roll-on and head hanging maneuvres under video nystagmography monitoring and air conduction cVEMP on 102 patients with benign paroxysmal positional vertigo (BPPV). The study contained 36 males and 66 females with the ages ranging from 16 to 71 years. Patients were grouped based on age, site of canal involvement, duration, severity, recurrence, and so on and results were compared with each group. Authors reported that 24 patients showed abnormality in VEMP. However, there was no correlation between abnormal VEMP and factors such as, effect of age, severity of nystagmus, site of canal involvement and the number of maneuvres applied. Study concluded that VEMP is one of the useful tools to assess otolith organs and this should be included the test battery of BPPV.

2.2. Applications of video head impulse test (vHIT) in various vestibular disorders

2.2.1. Meniere's disease

Blodow et al. (2014) reported that, video head impulse test and caloric test were more often abnormal in patients with Meniere's disease. Horizontal vestibular ocular reflex assessment with caloric test was most of the time abnormal than the video head

test. That is why both tests can be used complementary. Total 30 patients with Meniere's disease were evaluated on both the tests. Results of this study suggested, the caloric test was abnormal in 67% patients while video head impulse test showed horizontal VOR deficit in 37% patients with Meniere's disease. 28 % of individuals with abnormal caloric test showed normal vHIT and 6% of those with an abnormal vHIT showed normal caloric test. Authors found that sensitivity of vHIT was higher compared to caloric test in individuals with Meniere's disease. Not only caloric but also vHIT could not detect an early i.e. less than 5 years or advanced stages i.e. more than 5 years of Meniere's disease.

Cerchiai, Navari, Dalla, Sellari-Franceschini and Casani (2016) reported a retrospective study on 70 patients with unilateral Menier's disease. These patients further divided into two groups in which first group (16 patients) was treated with intratympanic gentamicin and second group (54 patients) was undergone only a conservative therapy. The major outcome of their study was the high frequency VOR gain was normal when individuals were treated with conservative therapy whereas, it was affected in individuals who were treated with intratympanic gentamicin. Results showed that, there was significant reduction in the high frequency VOR gain in first group. Authors further concluded that conservative therapy cannot lead to reduction in high frequency VOR gain However, gentamicin can lead to reduce the high frequency VOR gain, and hence this reduction can be taken into consideration while determining the effectiveness of an oblative treatment.

Cordero-Yanza et al (2017) concluded that patients with Meniere's disease can have vertical semicircular canal dysfunction which cannot be assessed by caloric vestibular test whereas it can be spotted by evaluating those patients on video head impulse test. Hence both vHIT and caloric tests should be used complementary. Authors

reviewed 88 patients of Meniere's disease and they found that 67% of patients showed abnormality on caloric vestibular test and 66% showed abnormal vHIT. There was poor agreement between both tests irrespective of horizontal SCC or all semicircular canals. Also 30% patients showed abnormal anterior semicircular canal pathology while 51% showed altered gain in posterior semicircular canal.

Fukushima et al. (2018) reported that video head impulse test and caloric test correspond to each other but reacts opposite to Meniere's disease and this opposite reaction may occur due to the high specificity but low sensitivity of canal paresis in the horizontal plane of video head impulse test. They also stated that, the volume of endolymphatichydrops affects caloric test results but does not affect results of video head impulse test. Authors had taken total 90 patients with Meniere's disease. All patients underwent neuro-otological evaluation including vHIT and gadolinium enhanced magnetic resonance imaging. Results showed that abnormal results were high in posterior semicircular canal (44.4%) followed by horizontal semicircular canal (13.3) and anterior semicircular canal (10%). The difference in the endolymphatic hydrops between the presence and absence of canal paresis was not significant when individuals evaluated with video head impulse test (P=0.5591) however, there was significant difference between both when tested with caloric test (P=0.0467).

2.2.2. Vestibular neuritis

MacDougall et al. (2009) recorded horizontal impulse test simultaneously with video head impulse test (250Hz and search coil (1000Hz). Eight normal individuals, six subjects with vestibular neuritis, one individual after intratympanic gentamicin and one individual with bilateral gentamicin vestibulotoxicity were included in their study. There was no significant difference in the visual ocular reflex gain of search coils and video head impulse test.

Bartolomeo et al. (2014) evaluated the performance of video head impulse test (vHIT) in individuals with vestibular neuritis. 29 patients with vestibular neuritis were included in this study. Authors assessed semicircular canals functioning in the initial presentation as well as after 1-3 months follow-up by administering vHIT and caloric testing. At the follow-up visit, complete recovery occurred in 31 % of cases according to caloric evaluation, and vHIT normalized in 51.8 %. The receiver operating curve (ROC) showed that specificity and sensitivity of vHIT were 100 % when the caloric deficit was respectively lower than 40 % or higher than 62.5 %. At the caloric testing value of 30 %, specificity was 100 %, sensitivity 68.84 %, positive predictive value 100 % and negative predictive value 62.5 %. Authors concluded that vHIT is a fast, convenient and specific test to detect vestibular deficits in vestibular neuritis. However, vHIT lacks sensitivity by comparison with caloric testing, especially for moderate vestibular lesions.

Air conduction cVEMP and air conduction oVEMP along with video head impulse test allows a better differentiation of receptor involvement in vestibular neuritis (Walther, &Blödow, (2013). Authors assessed 20 normal individuals and 20 patients with vestibular neuritis based on the air conduction cVEMP and air conduction oVEMP along with video head impulse test in 3 planes. And results of their study showed that these all three test gives differentiation of four types of vestibular neuritis such as inferior vestibular neuritis, superior vestibular neuritis, ampullary vestibular neuritis and entire vestibular neuritis.

2.2.3. Vestibular Schwannoma

Constanzo, Teixeira, Sens and Ramina (2019) reported that cystic vestibular schwannoma leads to worse dysfunction. Total 41 patients with sporadic, untreated schwannoma were involved in the study. These patients were further divided into Solid,

Cystic and heterogeneous types of tumours. Authors found that large vestibular schwannoma had significantly poor VOR gain than the small sized vestibular schwannoma ($p<0.001$). Results also talked about worse VOR gain in cystic vestibular schwannoma when compared to other types of tumours.

2.3. Vestibular disorders in Diabetes Mellitus

2.3.1. Anatomical correlates

Myers and Ross (1987) reported that there was increased amount of secondary lysosomes within the connective tissue cells and also an accumulation of intracellular lipid droplets which increased the level of hyperglycemia. The influence of long term diabetes on the saccule and utricle was diagnosed with light and electron microscopy. The accumulation of extracellular matrix was seen in five animals that had relatively more severe diabetes. Also small amount of type I hair cells were observed in two of these rats with longer duration of diabetes. This degeneration occurred possibly due to impaired diffusion of nutrients, oxygen and waste material through the dense extracellular matrix. However, utricles of these animals did not show any type of degeneration of hair cells.

Gawron, Pospiech, Orendorz-Fraczkowska and Noczynska (2002) reported that the metabolic disturbances were seen in type I diabetes mellitus and it also leads to cause disturbances in different parts of the vestibular system but majorly it was seen in the central part. The degree of disturbances of vestibular organs seemed to be dependent on the characteristics of hypoglycaemia incidents, duration of the diabetes and the compensation of the diabetes. The study consisted of 95 normal children and young adults with type I diabetes and 45 normal children and young adults in the age of 6 to 28 years. All individuals were evaluated on electronystagmographic test using the computed two-canal electronystagmographer. Six patients from diabetic group

complained about vertigo and balance disorder. Positional nystagmus occurred in 21 patients and 10 patients showed spontaneous nystagmus. Thirty three patients showed impaired eye tracking test whereas, 36 showed impaired optokinesis. The caloric test reported directional preponderance in 7 patients and canal paresis in 4 patients.

Klagenberg, Zeigelboim, Jurkiewicz, and Martins- Bassetto (2007) reported that significant changes were seen in peripheral vestibular system (60%) than auditory system (10.0%) and also patients had vestibular deficiency syndrome. Authors did a cross-sectional study and 30 participants were involved. Otological inspection, audiometry, vestibular function test were carried out along with detailed medical history. Authors found that 23.3% patients reported to have headache, 16.6% vertigo and 13.3% tinnitus. Nearly 90% of people showed normal auditory thresholds with no change in their acoustic impedance however, 60% patients showed changes in vestibular tests.

2.3.2. Vestibular evoked myogenic potentials in diabetes mellitus

Li et al. (2008) studied the changes in vestibular functions in individuals with diabetes mellitus using Electronystagmography. Total 136 subjects were included in the study. These individuals were further divided into 2 groups. Group I consisted of 76 individuals with diabetes mellitus and group II consisted of control group of 60 individuals. Authors also evaluated both the groups based on spontaneous nystagmus, head shaking nystagmus, positional test, neck torsion test, caloric test as well as sensory organization tests. The results of their study showed that 68.4% individuals were diagnosed with vestibular dysfunction in group I and 8.3% individuals with vestibular dysfunction in group II control group and indicated the significant difference between these two groups. Authors concluded that dizziness or vertigo occurred in patients with diabetes mellitus might be related to dysfunctioning of vestibular system.

Su et al. (2015) found clinical values of cervical VEMP and Occulomotor VEMP in the diagnosis of vestibular nerve impairment in individuals with type II diabetes mellitus. 42 individuals (84 ears) with diabetes mellitus and 42 normal individuals (84 ears) were included in this study. Both the groups underwent cVEMP and oVEMP tests and results of these tests were compared between the groups. Results of this study suggested that in the control group cVEMP and oVEMP were present in total 74 ears and 70 ears respectively. In the diabetic group cVEMP was present in 53 ears and oVEMP was present in 49 ears. Also significantly prolonged P1, N1 latencies of oVEMP and cVEMP were observed in diabetic population as compared to normal whereas, No significant difference was seen between the two groups in cVEMP and oVEMP parameters (latency interval, amplitude and threshold). Authors concluded that, there was some degree of involvement of vestibular nerve impairment in diabetic individuals.

Sahu and Sinha (2015) reported a study on assessment of sacculocollic pathway in patients with diabetes mellitus. In this study total 30 participants were included in the age range of 30-60 years; 15 with diabetes mellitus and 15 without diabetes mellitus. cVEMP was recorded followed by routine audiological evaluation in both groups. The results of this study showed that cVEMP was present in all individuals of control group whereas in 8 individuals of diabetic group. Also there was a significant difference in latency of N1 and P1 complex between the groups. Authors made a conclusion that sacculocollic pathway can get affected in patients with diabetes mellitus.

Konukseven et al. (2015) implemented air conduction ocular and cervical VEMP in diabetic and pre-diabetic individuals. In this study 30 diabetic patients, 30 pre diabetic patients and 31 normal age & sex matched individuals (control group) were tested. In results authors stated that in oVEMP and cVEMP latencies of p1, n1 were longer in diabetic group when compared with pre diabetic group and control group individuals. In

the diabetic group, prevalence of pathological p1 and n1 latencies in oVEMP were 30.4% and 37.5%, whereas they were 53.7%, 59.3% in cVEMP, respectively. Authors concluded that, vestibular neuropathy can be one of the complications of diabetes.

Ward et al. (2015) localized the vestibular dysfunction in individuals with type 2 diabetes mellitus. Authors assessed 25 diabetic individuals and 25 non diabetic individuals based on cVEMP, oVEMP and head thrust dynamic visual acuity tests to check the functioning of saccule, utricle and semicircular canals respectively. From their study authors found that the dysfunctioning of semicircular canal (at least 1 semicircular canal) was more common than the dysfunctioning of otolith organs. Superior and lateral semicircular canal function was affected more in diabetes group whereas; posterior semicircular canal function was similar to non diabetic group. The cVEMP and oVEMP test results showed decreased peak to peak amplitude. Authors concluded that individuals with diabetes mellitus performed poorly as compared to age matched non diabetic individuals.

Minnaar and Danielle (2017) reported a cross sectional study on diabetic patients with mean age of 49.1 years and who had diabetes since 15.36 years. Authors compared the audiovestibular function, health related quality of life (HRQL) and risk of falling in type 2 diabetic individuals and age and gender matched control group individuals. All individuals of both the groups underwent pure tine audiometry and ocular vestibular evoked myogenic potentials. There was 1.5 times greater risk for having absent cVEMP and 1.3 times higher risk of absent oVEMP responses in individuals with type 2 diabetes mellitus.53.6% of the type 2 diabetic patients showed absent cVEMPs (unilateral/bilateral), compared to 25% of the non-diabetic controls. Further authors found that oVEMP (unilateral/bilateral) was absent in 74.1% of the type 2 diabetic patients compared to 53.6% of the non-diabetic control group individuals. Authors

concluded that, there were higher chances of audiovestibular dysfunction, poorer HRQL and high risk of falling in diabetic individuals compared to non diabetic individuals.

2.3.3. Video head impulse test in diabetes mellitus

Nicholson, King, Smith and Darlington (2002) evaluated 41 individuals with diabetes mellitus (18 had Insulin dependent diabetes mellitus and 23 had non-insulin dependent diabetes mellitus) and 45 non diabetic normal individuals were involved in the study. All individuals were evaluated on vestibulo-ocular reflex along with on postural function and optokinetic reflex tests. Authors found that there was no significant difference in VOR gain between the groups. Nevertheless, there was a significant difference phase re velocity. Post-hoc analysis results indicated significantly longer phase re velocity for active rotation in individuals with Non-insulin dependent diabetes mellitus than the normal control group individuals ($p<0.05$), whereas it was shorter in individuals with insulin dependent diabetes mellitus than the control group ($p<0.01$) and non insulin dependent diabetes mellitus individuals ($p<0.05$). Authors concluded that both groups of individuals with diabetes mellitus showed deficits in changes in phase re velocity.

Cardenas-Robledo, Tehrani, Blume and Kattah (2016) reported that, in patients with Maternally-inherited diabetes mellitus and deafness (MIDD) had loss of vestibular function which leads to poor dynamic visual acuity. Authors administered video head impulse test on two unrelated MIDD individuals and obtained VOR for vertical and horizontal semicircular canals. Results showed that, two patients had decreased VOR gain in all the planes of three semicircular canals and had an abnormality of visual, ocular motor and vestibular system.

Minnaar et al. (2017) reported a cross sectional study in diabetic individuals with mean age of 49.1 years and who had diabetes since 15.36 years. All the individuals were

evaluated on video head impulse test. Authors reported that, there was no significant difference in the results of video head impulse test between the two groups. However, significant difference was seen in the presence of saccades for right lateral canal between the two groups (p=0.002; McNemar test of symmetry). Authors conclude that diabetic individuals showed higher risk of vestibular dysfunction than the non diabetic individuals.

Kalkan et al (2018) stated the study on type II diabetes mellitus individuals with or without polyneuropathy. In this study three groups were taken; 1st group included 33 patients with type II diabetes mellitus; 2nd group included 33 patients with diabetic polyneuropathy and the last group included 35 age and sex matched control group. Video head impulse test were recorded in all individuals. The results of this study showed that there was no statistical significant differencein VOR gain between the groups.

To summarise, although there are many studies indicating possible involvement of vestibular system in individuals with diabetes mellitus, these studies are equivocal. Also, there is a dearth of information on VOR functioning for all the six semicircular canals in individuals with diabetes. Hence this study was taken up with an aim of studying the saccular, utricular and semicircular canals function in individuals with diabetes.

Chapter III

METHOD

The present study aimed at evaluating sacullocollic pathway, ocular pathway and all the six semicircular canals in individuals with diabetes mellitus.

3.1. Participants

Total 56 individuals (37 males and 19 females) within the age range of 35 - 65 years participated in the study. The participants were divided into two groups-

Group I: This group included 28 individuals (19 males and 9 females) with type 2 diabetes mellitus.

Group II: This group included 28 individuals (18 males and 10 females) without any diabetes mellitus.

3.1.1. Participant Selection Criteria for Group I:

- All the participants had type 2 diabetes mellitus. Type 2 diabetes was confirmed through the medical reports.
- Individuals with having hearing sensitivity within normal limits or having sensorineural type of hearing loss.
- Individuals having retro cochlear pathology were excluded from the study by evaluating them on auditory brainstem response (ABR).
- Participants had no history of any conductive pathology.
- No history of spondylitis or presence of any other neuromuscular problem.
- Participants had no history of drug intake which can cause vestibular toxicity.

3.1.2. Participant Selection Criteria for Group II:

- The participant in this group had no diabetes mellitus.
- Individuals were not having any presence or history of conductive pathology.

- All participants in the group had normal hearing sensitivity or sensorineural type of hearing loss.
- No history of drug intake which leads to vestibular toxicity.

3.2. Instrumentation

- A calibrated two channelled inventis piano diagnostic audiometer with TDH-39 headphone (Telephonics, 815 Broad Hollow Road, Farmingdale, New York 11735) and B-71 bone vibrator (Radioear, KIMMETRICS, 22050 Mohawk Drive, Smithsburg, MD 21783) were used for obtaining air conduction and bone conduction thresholds respectively in individuals with and without diabetes mellitus..
- To rule out the middle ear pathology, immittance audiometry was performed by using GSI TYMPSTAR (GSI VIASYS Healthcare, Wisconsin, USA) instrument.
- To obtain C-VEMP and O-VEMP recording an INTELLIGENT HEARING SYSTEM (IHS) smart EP (3.91USBez) system (Intelligent Hearing System Florida, USA) and Biologic were used.
- To obtain VHIT responses GN Otometrics (GN Otometrics, Taastrup, Denmark) instrument was used.

3.3. Test environment

Ambient noise levels in an acoustically treated single room set up was maintained within the permissible limits [ANSI S3.1 (1991)].

3.4. Procedure

3.4.1 Case History

Case history for each individual was studied thoroughly along with this a dizziness questionnaire was administered.

3.4.2. Pure tone audiometry

Pure Tone Audiometry was performed for all the participants and thresholds were obtained for air conduction and bone conduction hearing for frequencies between 250 Hz to 8000Hz and 250Hz to 4000Hz respectively by using Hughson and Westlake method given by Carhart and Jerger (1959).

3.4.3. Uncomfortable loudness levels

Uncomfortable loudness levels were obtained for each individual using speech stimuli.

3.4.4. Immittance audiometry

Immittance audiometry was done for each participant for both ears by using 226Hz probe tone. Ipsilateral as well as contralateral reflex thresholds were measured at 500Hz, 1 KHz, 2 KHz and 4 KHz.

3.4.5. Auditory brainstem response:

ABR was performed to rule out the retrocochlear pathology. Surface disc AGCL electrodes were placed on the forehead, testing ear mastoid and non-test ear mastoid. The interelectrode impedance was maintained below 2 kΩ. Click was presented through an ER-3A insert earphone with an intensity of 90dBnHL at 11.1/sec and 90.1/sec repetition rate. Filter setting was kept constant for all the individuals i.e. 100 – 1500Hz. Total no. of 1500 sweeps were given for each recording.

3.4.6. Vestibular evoked myogenic potentials

Before putting silver chloride disc electrodes on the skin, the area was cleaned with the help of Neuprep gel and the electrodes were placed by using conducting gel. The inter-electrode impedance was maintained between 2 KΩ. A person was made to sit comfortably on the chair.

a). *Cervical vestibular evoked myogenic potentials recording:*

Non-Inverting electrode was placed on the midpoint of sternocleidomastoid (SCM) muscle on the same side being stimulated. Similarly an inverting electrode was placed on sternoclavicular joint and ground electrode on the lower forehead. Before giving the stimulus the participant was asked to turn his/her head right/left to activate the SCM muscle of the right/left side and maintain the head turn throughout the run cVEMP was recorded using 500 Hz tone burst stimuli presented at 95 dBnhl with a repetition rate of 5.1/sec. The total duration of the tone burst i.e. 2-0-2 cycles and total 200 sweeps were given for recording cVEMP. Total time window of 70 msec was used including 10 msecprestimulus duration. For the recording of cVEMP 30Hz and 1500Hz of high pass and low pass filter was used respectively with an amplification of 5000.

b). Ocular vestibular myogenic evoked potential:

Non-inverting electrode was placed immediately inferior to the lower eyelids (1cm below the eyes) to record oVEMP. Inverting electrode was placed 1 cm below the non-inverting electrode and Ground electrode on the lower forehead. oVEMP was recorded using 500 Hz tone burst of 2-0-2 cycle stimulus. Total 200 sweeps were presented at an intensity of 95dbnHL with the repetition rate of 5.1/sec. High pass filter of 1Hz and low pass filter of 1000Hz was used and the recording mode was kept as contralateral. The rarefaction polarity was used for the stimulus. Analysis time window of 60 msec and 10 msec of prestimulus duration was used. Obtained responses were filtered between 1 Hz to 1000 Hz.

3.4.7. Video head impulse test (vHIT) recording

The testing was carried out in an acoustically treated room. The person was asked to seat in an upright position on an adjustable chair. The goggle attached with the monocular camera was placed securely and tightened properly on individual's eyes.

Testing was 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 was asked to maintain his/her gaze on a target which was displayed on the front wall, nearly 1 meter away from him/her. The examiner was suddenly given a short and brief head impulse in a random way. The testing was administered in 3 different planes i.e. to evaluate the anterior and posterior SCCs. The head movements were done in left anterior-right posterior (LARP) and right anterior-left posterior (RALP). To check horizontal semicircular canals, the head movements were done in a lateral plane. Head of the participant was moved about 10-15degree and 20 head impulses were given for each side of the canal. For each head impulse the head and eye velocity and the ratio of head and eye velocity were measured through the software on a computer screen. Along with this the examiner also looked for saccades to check whether these were normal or abnormal.

3.5. Analysis

Analysis of cVEMP:

- The latency of peak ‘ P13' and N23 peaks were analyzed for both the groups
- Peak to peak amplitude of P13-N23 peak was calculated for both the groups.

Analysis of oVEMP

- The latency of peak ‘N1’, P1 and N2 was calculated for both the groups,
- Peak to peak amplitude of ‘N1-P1 and P1-N2’ peaks for both the groups were analysed.

Analysis of Video head impulse test

- VOR gain was calculated for both the groups. For calculation of VOR gain the eye velocity was divided by head velocity.
- Overt and covert saccades were marked if any present.

Chapter - IV

RESULTS

The study was conducted with an aim to assess the functioning of saccule, utricle and all six semicircular canals in individuals with diabetes mellitus. to achieve the aim 56 (28 diabetic; 28 non diabetic) subjects were taken. All individuals were evaluated on cervical vestibular evoked myogenic potentials (cVEMP), ocular vestibular evoked myogenic potentials (oVEMP) and Video head impulse test (vHIT). The cVEMP responses were present in 22 non diabetic individuals and 15 diabetic individuals. The oVEMP was present in 16 non diabetic individuals and 10 diabetic individuals. The results were summarized under following headings:

a. Cervical vestibular evoked myogenic potentials findings
b. Ocular vestibular evoked myogenic potentials findings
c. Video head impulse test findings
d. Correlation between VEMP parameters with duration of diabetes mellitus
e. Correlation between vHIT and duration of diabetes mellitus
f. Association between vestibular evoked myogenic potentials with degree of hearing loss

a. Cervical vestibular myogenic potentials findings

Latency of p1, n1 and peak-to-peak amplitude (p1n1) of cVEMP was analyzed in diabetic and non diabetic groups. In non diabetic group cVEMP was present in 45 ears out of 56 ears in non diabetic individuals; in 29 ears out of 56 ears in diabetic individuals.

cVEMP responses were recorded from one of the diabetic and non diabetic individuals with presence and absence of waveforms are shown in following figures. Figure 4.1 shows cVEMP present in both ears in one of the non diabetic individuals.

Figure 4.2 Shows cVEMP absent in both ears in one of the non diabetic individuals. Figure 4.3 shows cVEMP present in both ears in one of the individuals with diabetes mellitus. Figure 4.4 shows cVEMP absent in one of the individuals with diabetes mellitus.

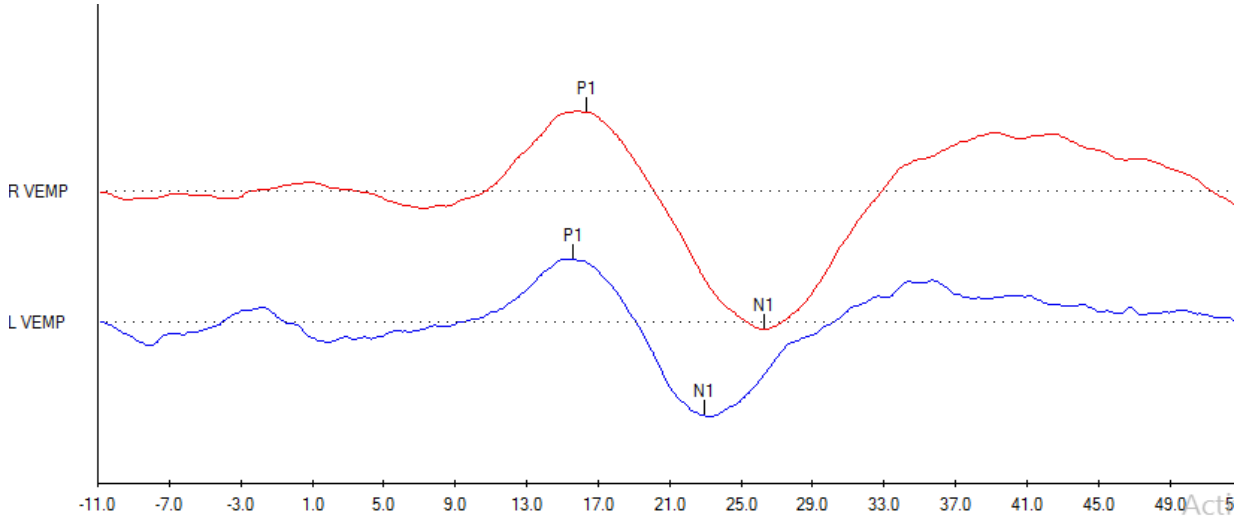

Figure:4.1. cVEMP waveforms in one of the non diabetic individuals in both ears with presence of cVEMP response.

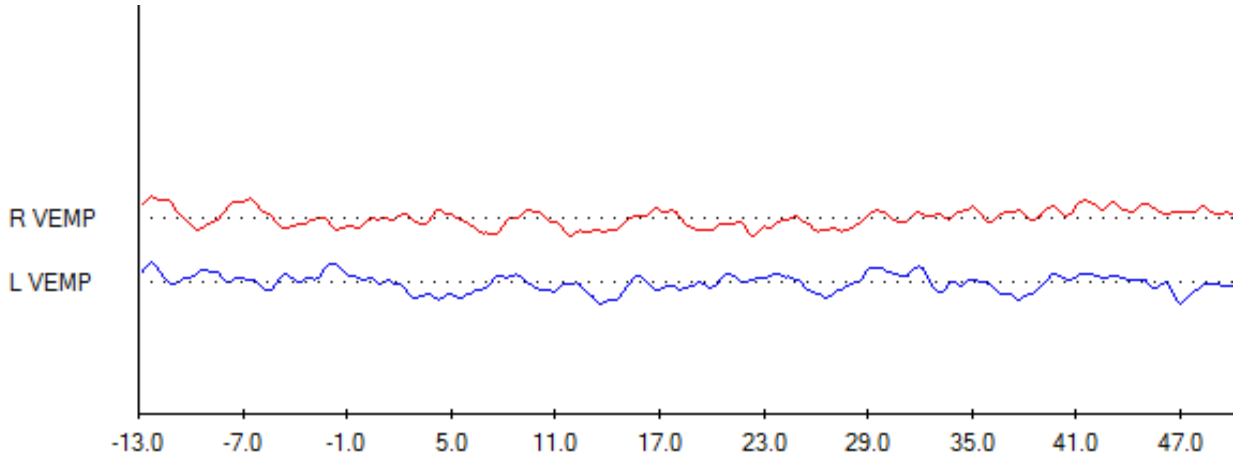

Figure:4.2. cVEMP waveforms in one of the non diabetic individuals with absence of cVEMP in both ears.

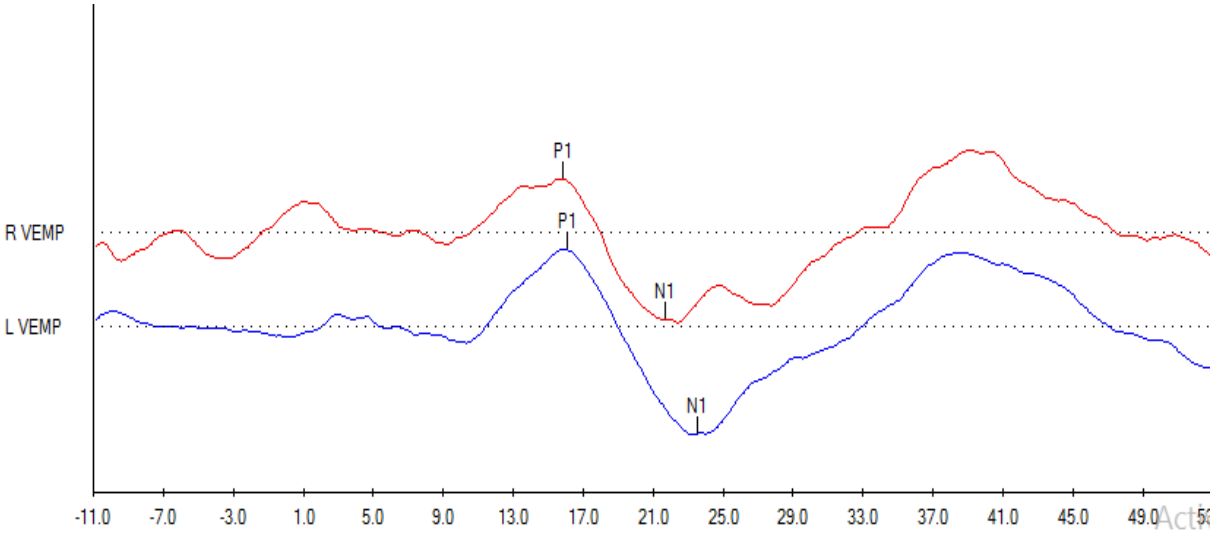

Figure:4.3. cVEMP waveforms in one of the diabetic individuals in both ears with presence of cVEMP response.

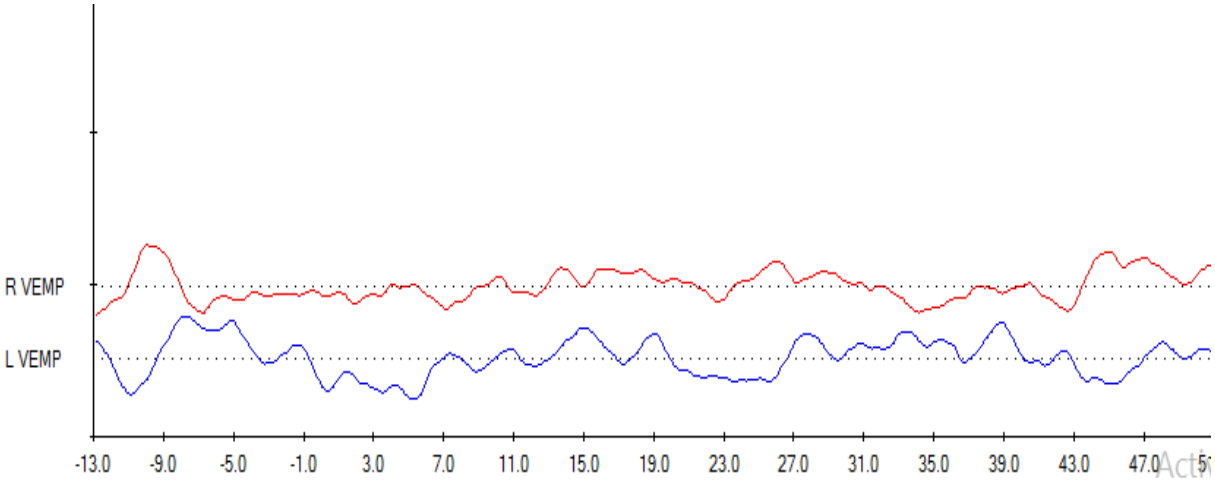

Figure:4.4. cVEMP waveforms in one of the diabetic individuals with absence of responses in both the ears.

Descriptive statistic was done to obtain the mean and standard deviation for the cVEMP. The parameters P1 latency, n1 latency and p1n1 peak-to-peak amplitude complex were assessed for both the groups. cVEMP was present in 45 ears of non diabetic group and 29 ears of diabetic group. The mean and standard deviations of cVEMP in diabetic and non diabetic group is shown in Tables 4.1 and Table 4.2.

Table:4.1.

Mean and standard deviation (SD) of cVEMP is shown in non diabetic group of indiivduals in right ear and left ear.

	Right ear			**Left ear**		
	N	Mean	SD	N	Mean	SD
p1 latency (in msec)	22	15.01	1.19	23	15.3	1.19
n1 latency (in msec)	22	22.63	1.89	23	23.09	1.39
p1-n1 amplitude	22	92.96	104.49	23	97.61	76.57

Table: 4.2.

Mean and standard deviation (SD) of cVEMP is shown in diabetic group of individuals in right ear and left ear.

	Right ear			**Left ear**		
	N	Mean	SD	N	Mean	SD
p1 latency (in msec)	15	15.2	1.82	14	15.1	1.43
n1 latency (in msec)	15	22.2	2.01	14	21.94	1.53
p1-n1 amplitude	15	33.87	43.52	14	33.64	41.17

It can be seen from Table 4.1 and Table 4.2 that, cVEMP responses were present in 22 right ears and 23 left ears of non diabetic individuals whereas, it was present in 15

right ears and 14 left ears of 28 individuals with diabetes. In non diabetic individuals the mean values of p1 latency in right ear is less than diabetic individuals whereas, mean values of p1 latency is greater in left ear of non diabetic individuals than in diabetic individuals. Mean of n1 latency in non diabetic group is greater than mean n1 latency in diabetic individuals. It was seen that mean of p1n1 peak-to-peak amplitude was less in diabetic populations than in non diabetic populations in both the ears.

Shapiro Wilk test was done to check the normality distribution of the data. Shapiro Wilk test revealed normal distribution of the data for both the groups ($p>0.05$). The paired sample t-test was performed to compare p1,n1 latencies and p1n1 peak-to-peak amplitude of right ear and left ear in diabetic group and non diabetic group. The data of paired sample t-test is shown in Table 4.3. includes t values, degrees of freedom (df) and significant values of p1 latency of right ear and left ear of non diabetic group, n1 latency of right ear and left ear of non diabetic, p1 latency of right ear and left ear, n1 latency of right ear and left ear of diabetic group and p1n1 amplitude of right ear and left ear.

Table 4.3.

Paired sample t-test values to compare right ear and left ear in non diabetic group and diabetic group.

		t	df	Sig. (2-tailed)
Non diabetic group	p1 latency right ear – p1 latency left ear	1.34	20	0.19
	n1 latency right ear – n1 latency left ear	0.83	20	0.41

	Right p1n1-Left p1n1	0.03	20	0.99
Diabetic group	p1 latency right ear – p1 latency left ear	0.20	11	0.84
	n1 latency right ear – n1 latency left ear	1.29	11	0.22
	Right p1n1-Left p1n1	0.21	11	0.83

The results of paired sample t-test showed that, there was no significant difference in latencies of p1 and n1 and p1n1 peak-to-peak amplitude in right ear and left ear of both the groups. Hence, the data of right ear and left ear was combined in both the groups to obtain mean and standard deviations for latency and amplitude of cVEMP. The descriptive analysis of combined mean and standard deviations in both diabetic and non diabetic group is shown in Table 4.4.

Table: 4.4.

Combined mean and standard deviations of p1, n1 latency and p1n1 peak-to-peak amplitude for non diabetic and diabetic group.

	Non diabetic		**Diabetic**	
	Mean	SD	Mean	SD
p1 latency (msec)	15.2	1.19	20.08	1.61
n1	22.8	1.65	26.33	1.77

latency(msec)				
P1n1 amplitude (µv)	118.58	86.49	65.19	36.58

It can be seen from Table 4.4 that, the mean value of p1 latency and n1 latency is short in non diabetic individuals than in diabetic individuals. The p1n1 peak-to-peak amplitude in non diabetic individuals was more than in diabetic individuals. The mean and standard deviation of p1 and n1 latency in diabetic and non diabetic group is show in figure 4.5. Mean and standard deviation of p1n1 amplitude of cVEMP in non diabetic and diabetic individuals are shown in figure 4.6.

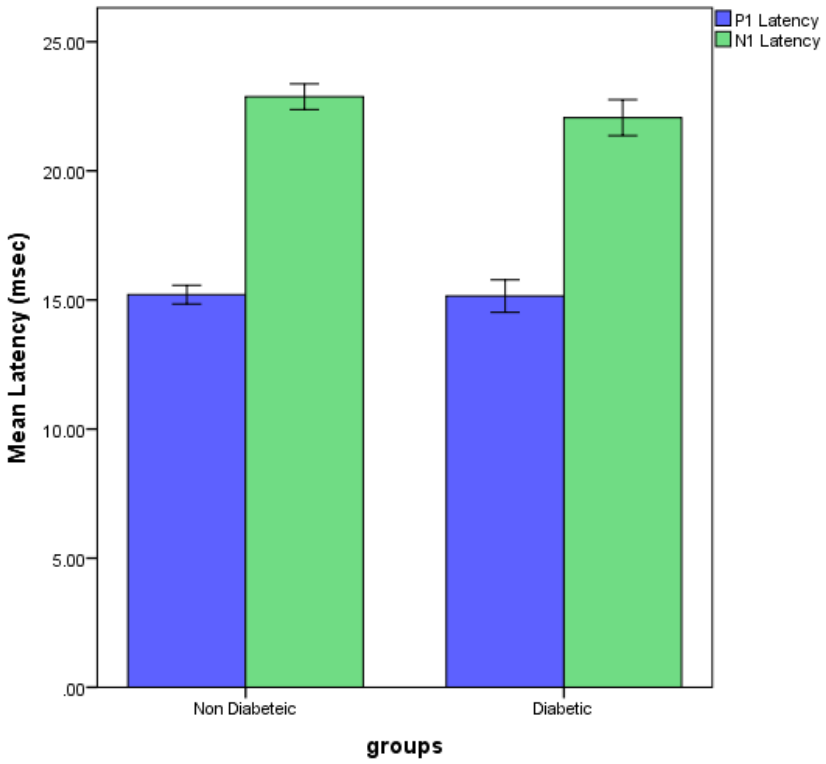

Figure: 4.5. Latency of p1 and n1 in non diabetic and diabetic individuals

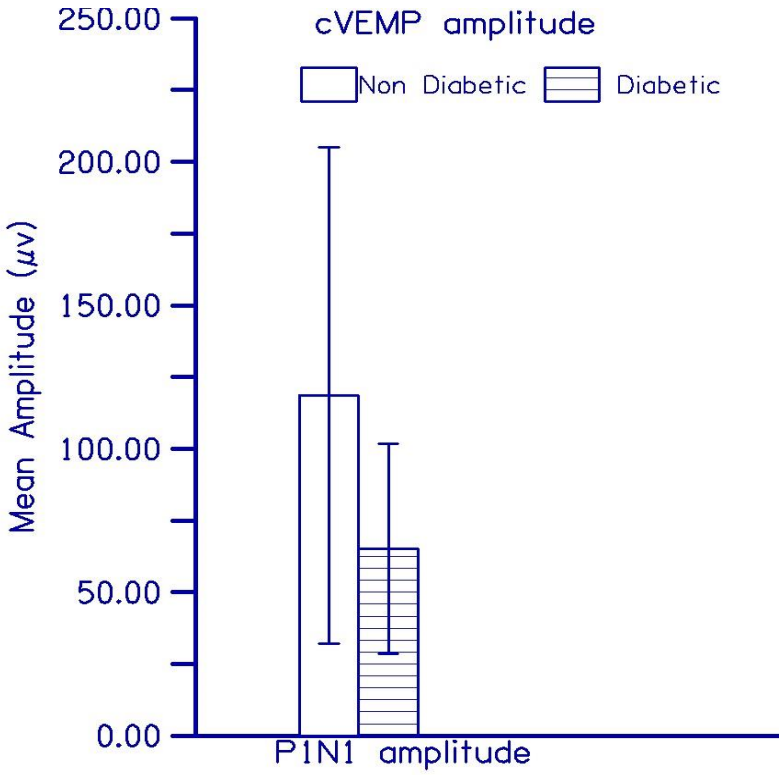

*Figure: 4.6.*Mean amplitude of p1n1 in non diabetic and diabetic individuals.

Although the data showed normal distribution but there was different number of data samples in both the groups. Hence a non parametric was performed to compare latencies of p1, n1 and p1n1 peak-to-peak amplitude for both the groups. Mann Whitney U test revealed that, there was no significant difference in the latencies of p1 (Z= 0.07; p= 0.93) and n1 (Z=-1.70; p= 0.88) in diabetic and non diabetic individuals. However, Mann Whitney U test revealed significant difference in the p1n1 peak-to-peak amplitude (Z= 2.52; p= 0.01) between the diabetic group and non diabetic group.

b. Ocular vestibular evoked myogenic potentials

Latency of n1, p1, n2 and peak-to-peak amplitude p1n1 & p1n2 were analyzed. oVEMP was present 33 ears out of 56 ears in individuals without diabetes. In diabetic individuals it was present in 19 ears out of 56 ears.

The recorded waveforms of oVEMP in one of the individuals of diabetic group and non diabetic group with presence and absence of responses are shown; Figure 4.7

shows presence of oVEMP response in one of the non diabetic individuals in both ears. Figure 4.8 shows absence of oVEMP responses in one of non diabetic individuals in both the ears. Figure 4.9 shows presence of oVEMP responses in one of the diabetic individuals in both the ears. Figure 4.10 shows absent oVEMP responses in one of the diabetic individuals in both the ears.

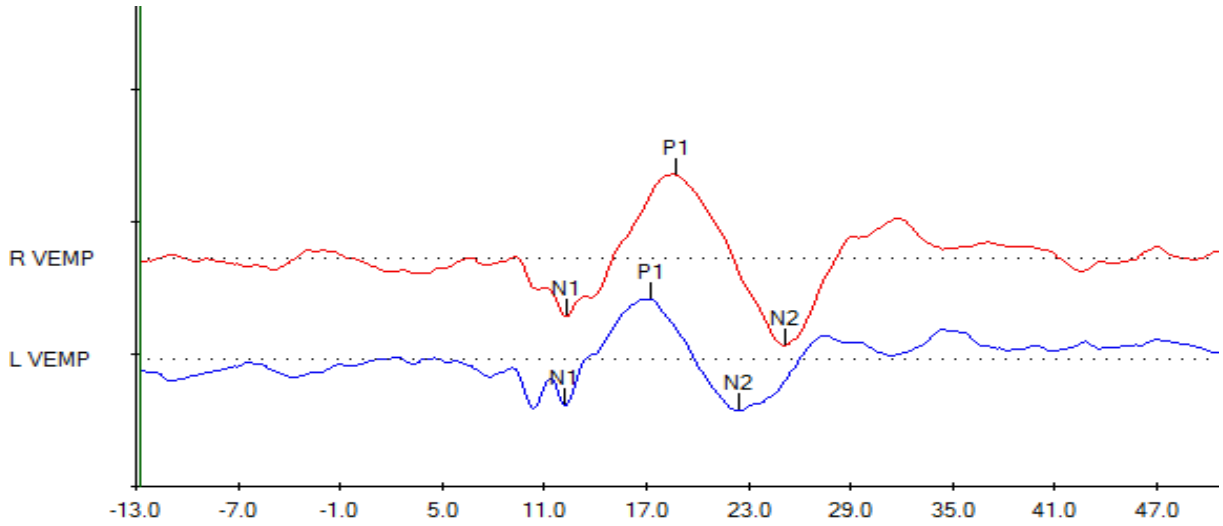

Figure:4.7. oVEMP waveforms in one of the non diabetic individuals in both ears with presence of oVEMP response.

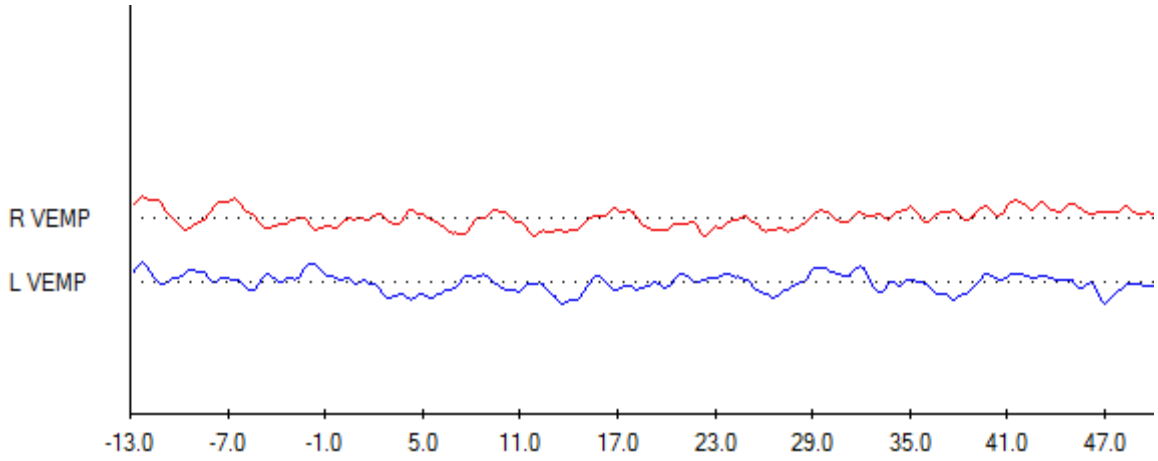

Figure:4.8. oVEMP waveforms in one of the non diabetic individuals with absence of oVEMP in both the ears.

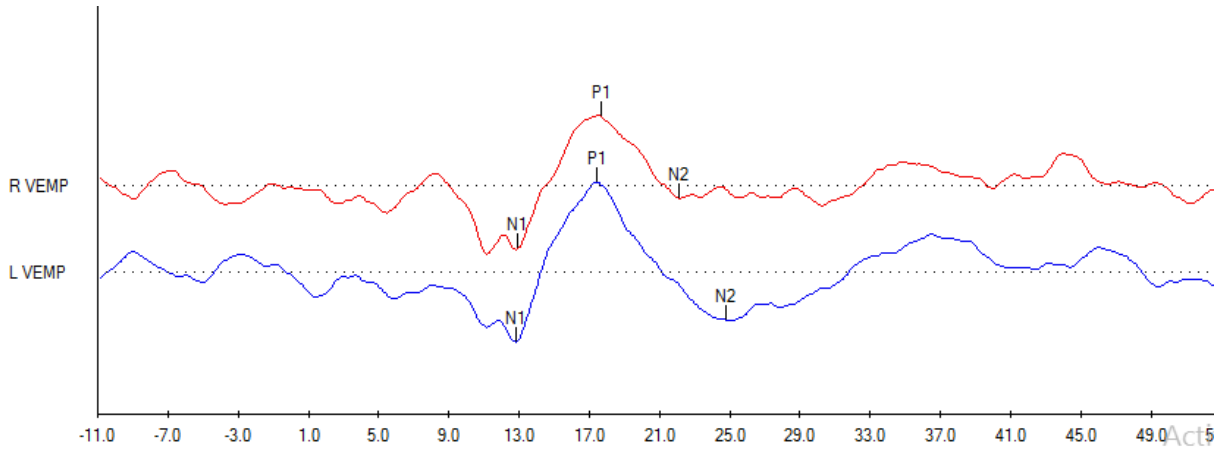

Figure:4.9. oVEMP waveforms in one of the individuals with diabetes mellitus with presence of oVEMP in both the ears.

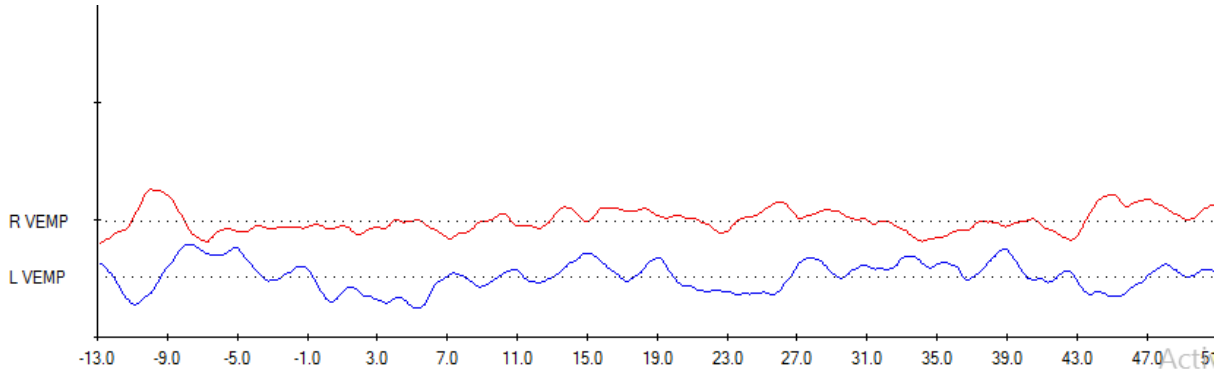

Figure:4.10. oVEMP waveforms in one of the diabetic individuals in both ears with absence of oVEMP response.

Descriptive statistics was done to measure the mean and the standard deviation of n1, p1 & n2 latency and the p1n1 & p1n2 peak to peak amplitude of oVEMP for both the ears in diabetic individualsand non diabetic individuals. The mean values and the standard deviation for n1, p1, n2 latency and p1n1 and p1n2 peak-to-peak amplitude of non diabetic and diabetic individuals are shown in Table 4.5 and Table 4.6 respectively.

Table: 4.5.

Mean and standard deviation (SD) of oVEMP in non diabetic individuals for right ear and left ear.

	Right ear	**Left ear**

	N	Mean	SD	N	Mean	SD
n1 latency (in msec)	16	12.14	1.41	17	12.44	1.16
p1 latency (in msec)	16	17.17	1.46	17	17.74	1.33
n2 latency (in msec)	16	21.86	1.56	17	23.97	3.07
n1-p1 amplitude (µV)	16	7.04	14.78	17	6.39	10.97
P1-n2 amplitude (µV)	16	5.48	10.38	17	5.43	8.56

Table: 4.6.

Mean and standard deviation (SD) of oVEMP in diabetic individuals in right ear and left ear.

	Right ear			**Left ear**		
	N	Mean	SD	N	Mean	SD
n1 latency (in msec)	10	12.12	1.46	9	11.62	1.32
p1 latency (in msec)	10	16.83	1.56	9	17.19	1.79
n2 latency (in msec)	10	21.67	2.00	9	21.70	1.61

n1-p1 amplitude (µV)	10	1.86	3.24	9	2.46	5.43
P1-n2 amplitude (µV)	10	1.82	2.68	9	1.59	2.75

It can be seen from Table 4.5 and Table 4.6 that, in the right ear the mean values of latencies of peak n1, p1 and n2 were longer in non diabetic individuals than the mean values of latencies of n1, p1 and n2 in diabetic individuals. Also in the left ear the mean values of latencies of peak n1, p1 and n2 were longer in non diabetic individuals than the mean values of latencies of n1, p1 and n2 in diabetic individuals. Whereas, the p1n1 peak-to-peak amplitude in the right ear of diabetic individuals is less than p1n1 peak-to-peak amplitude in the right ear of non diabetic individuals. Also the p1n2 peak-to-peak amplitude in the right ear of diabetic individuals is less than less than p1n2 peak-to-peak amplitude in the right ear of non diabetic individuals. It can also be seen that in the left ear of diabetic individuals the amplitude of p1n1 and p1n2 is less than the p1n1 and p1n2 in non diabetic individuals in left ear. oVEMP was present in 16 right ears and 17 left ears out of 56 ears in non diabetic individuals. In diabetic individuals it was present in 10 right ears and 9 left ears out of 56 ears.

Shapiro Wilk test for normality was performed and results revealed normal distribution of the data. Paired sample t-test, test for normality was performed to compare between right ear and left ear of diabetic individuals and non diabetic individuals. The data of paired sample t-test is shown in Table 4.7. includes t values, degrees of freedom (df) and significant values of p1 latency of right ear and left ear of

non diabetic group, n1 latency of right ear and left ear of non diabetic, p1 latency of right ear and left ear, n1 latency of right ear and left ear of diabetic group and p1n1, p1n2 amplitude of right ear and left ear in diabetic and non diabetic group.

Table 4.7.

Paired sample t-test values to compare right ear and left ear in non diabetic group and diabetic group.

		t	df	Sig. (2-tailed)
Non diabetic group	n1 latency right ear - n1 latency left ear	0.20	12	0.84
	p1 latency right ear- p1 latency left ear	1.70	12	0.11
	N2 latency right ear- n2 latency left ear	1.93	12	0.78
	Right p1n1- Left p1n1	0.93	12	0.36
	Right P1n2- Left p1n2	0.47	12	0.96
Diabetic group	n1 latency right ear -n1 latency left ear	0.52	8	0.61
	p1 latency right ear-p1 latency	1.01	8	0.34

left ear			
n2 latency right ear-n2 latency left ear	0.12	8	0.90
Right p1n1-Left p1n1	1.46	8	0.18
Right P1n1-Left p1n2	0.21	8	0.83

The result of paired sample t-test showed that, the right ear and left ear were not significantly different in terms of latency of n1, p1 and n2 peaks and p1n1 and p1n2 peak-to-peak amplitude in both diabetic group and non diabetic group. Hence the combined mean and standard deviations of n1, p1 and n2 latencies and p1n1 and p1n2 peak-to-peak amplitude were calculated in diabetic group and non diabetic group.

The combined mean and standard deviations for diabetic and non diabetic group is shown in table 4.8.

Table 4.8.

Mean and standard deviations of n1, p1, and n2 latencies and p1n1 and p1n2 peak-to-peak amplitude in ears of non diabetic and diabetic individuals

	Non diabetic			**Diabetic**		
	N	Mean	SD	N	Mean	SD
N1 latency	33	12.30	1.27	19	11.88	1.38
P1 Latency	33	17.46	1.40	19	17.02	1.63
N2 Latency	33	22.95	2.64	19	21.69	1.78

P1n1 amplitude	33	11.39	15.20	19	6.38	5.65
P1n2 amplitude	33	9.26	10.79	19	5.04	2.11

It can be seen from Table 4.8 that, oVEMP was present in 33 ears out of 56 ears in non diabetic individuals, However in diabetic group it was present only in 19 ears out of 56 ears. Mean values of p1n1 amplitude were more in non diabetic individuals than diabetic individuals. Also mean values of p1n2 in diabetic individuals is less than non diabetic individuals. The mean latencies of n1, p1 & n2 are shown in figure 4.11 and p1n1 and p1n2 peak-to-peak amplitude is shown in figure 4.12 in non diabetic group and diabetic group.

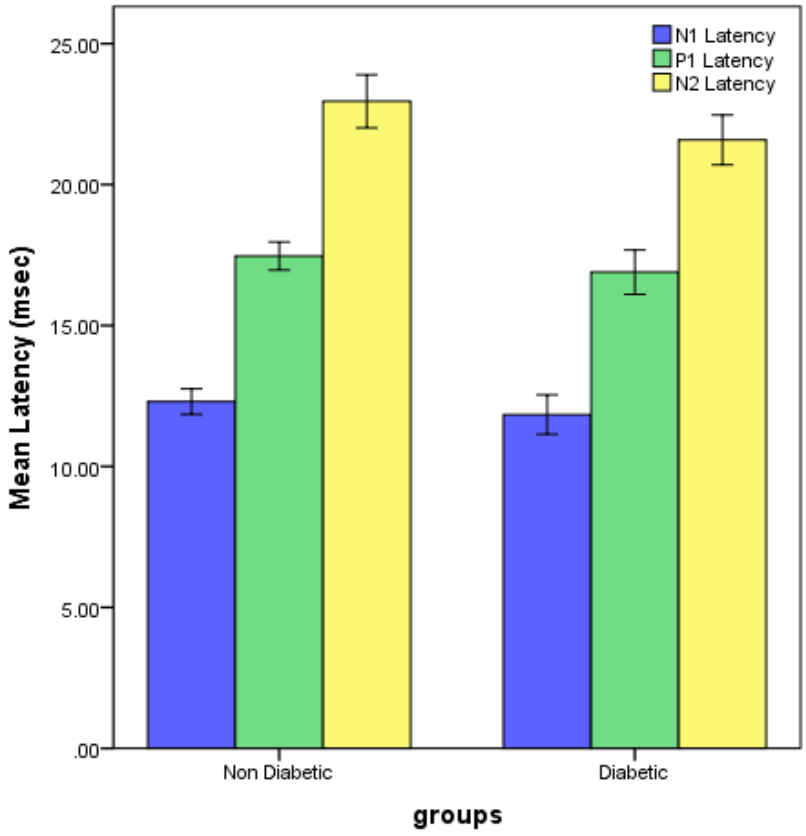

Figure: 4.11. Mean latency of n, p1 and n2 in non diabetic group and diabetic group.

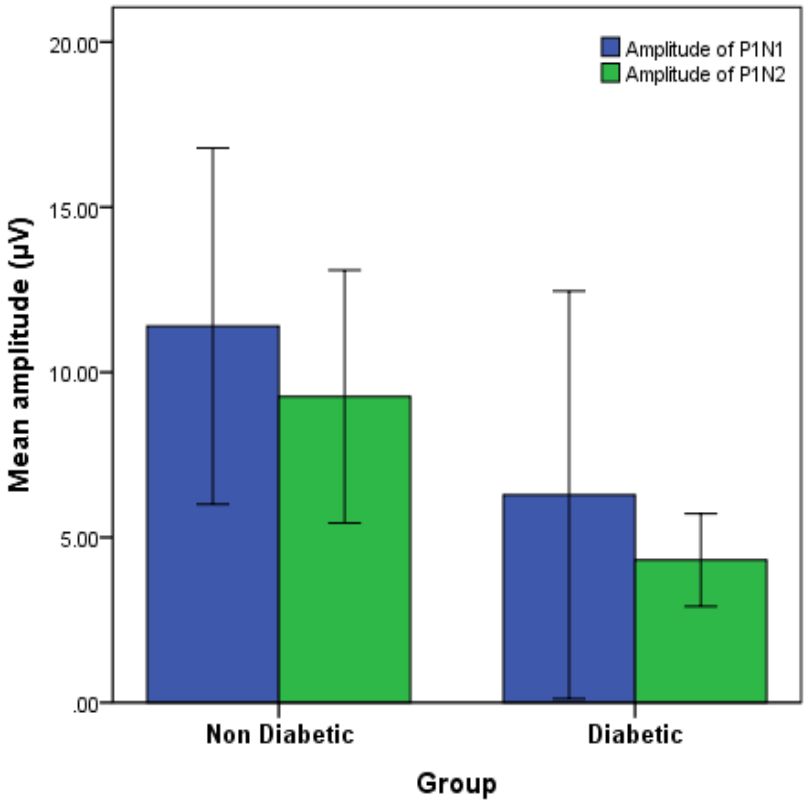

*Figure:4.12.*Amplitude of p1n1 and p1n2 peak-to-peak amplitude in non diabetic individuals and diabetic individuals.

To compare n1, p1 and n2 latencies of both the groups a non parametric Mann-Whitney U test was performed as there was different number of samples in both the groups. The results of Mann-Whitney U test revealed no significant difference in the latencies of n1 (Z= 0.84; p= 0.39), p1 (Z= 1.2; p= 0.23) and n2 (Z= 1.9; P= 0.056) between diabetic group and non diabetic group. Also there was no significant difference in the p1n1 peak-to-peak amplitude (Z=1.51; P= 0.13) and p1n2 peak-to-peak amplitude (Z=0.96; P= 0.33) between the diabetic group and non diabetic group.

c. Video head impulse test

Mean vestibulo-ocular reflex (VOR) gain and corrective saccades for all six semicircular canals (SCCs) were calculated in diabetic group and non diabetic group. Representative waveforms of vHIT obtained in non diabetic individuals are shown in figure 4.13 and individuals with diabetes are shown in figure 4.14 & figure 4.15.

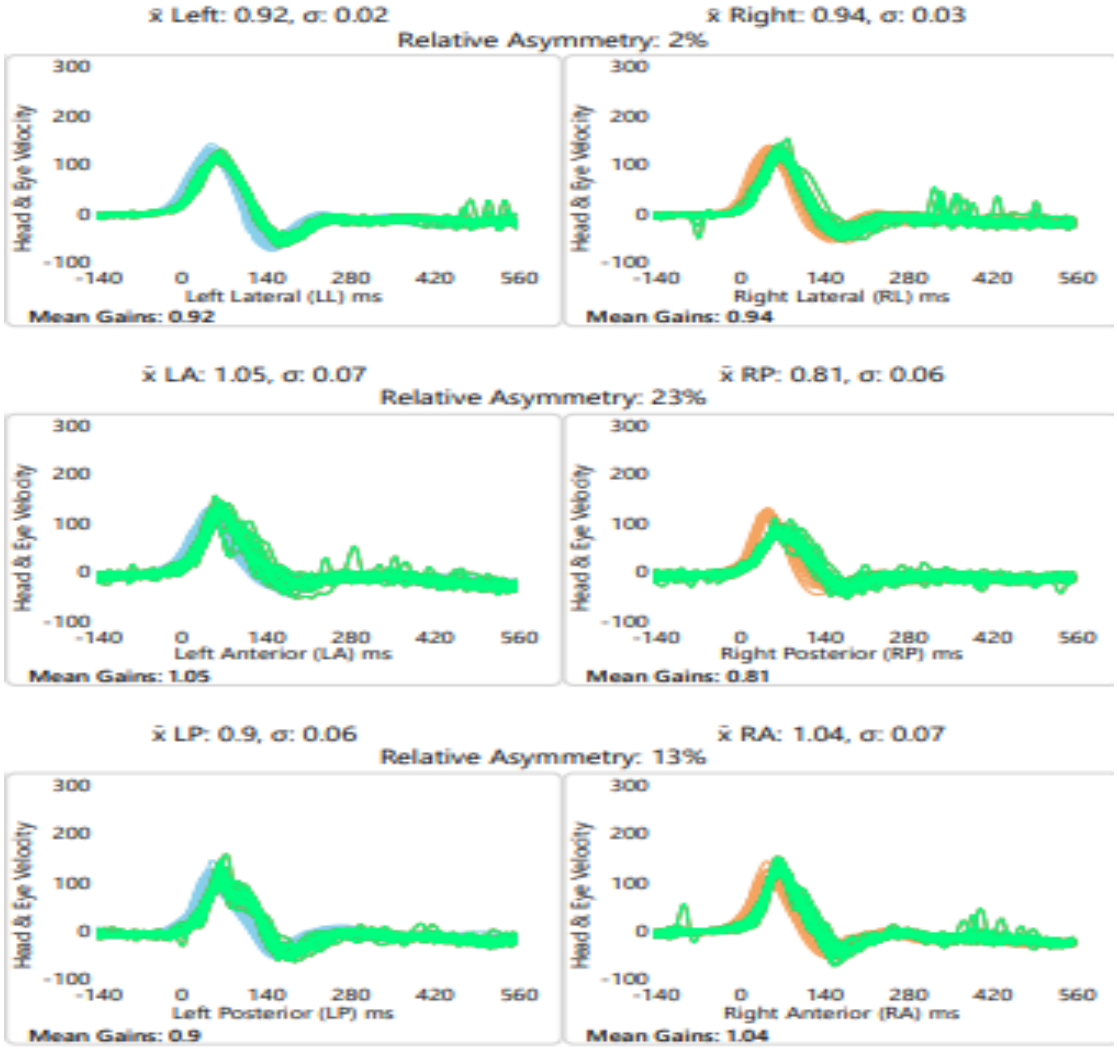

*Figure: 4.13.*Video head impulse test results of all six semicircular canals in 3 different planes in one of the non diabetic individuals. The head eye velocities throughout various head impulses are shown.

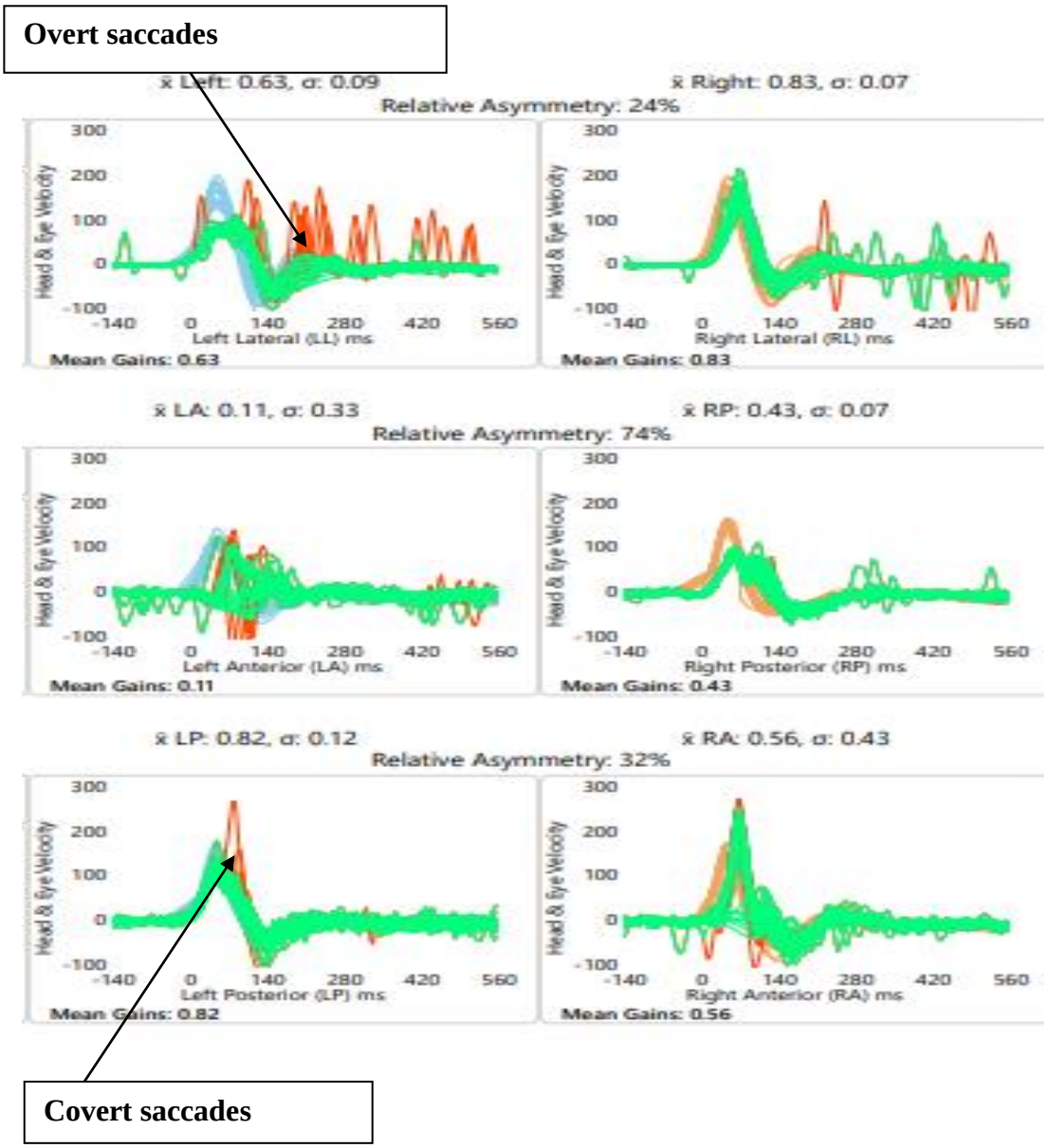

Figure: 4.14. Video head impulse test results of all the six semicircular canals in 3 different planes in one of the diabetic individuals. The head and eye velocities throughout various head impulses are shown. Presence of overt and covert saccades are seen in left lateral and left posterior canals.

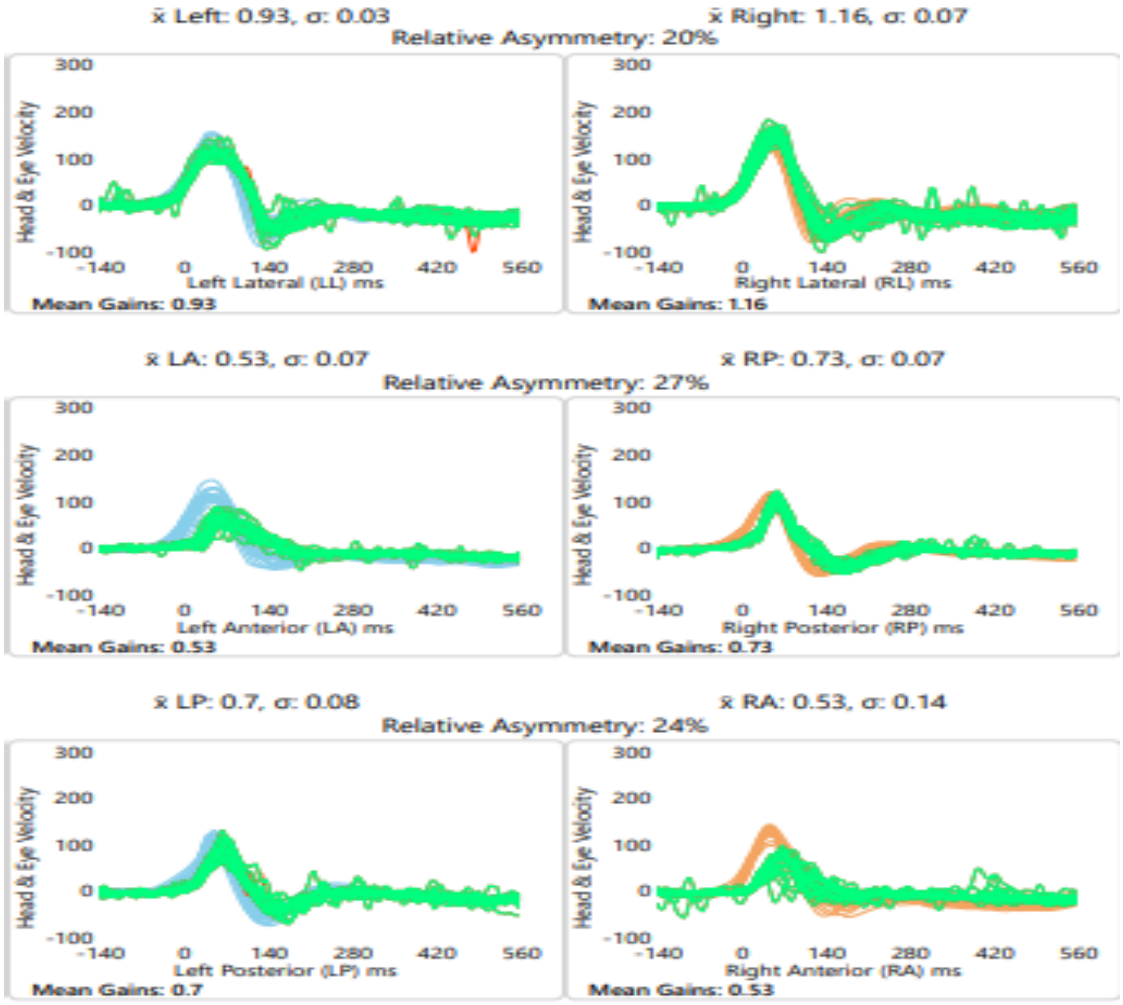

Figure: 4.15. Video head impulse test results of all six semicircular canals in 3 different planes in one of the diabetic individuals with reduced VOR gain in left anterior and right anterior semicircular canals. The head and eye velocities throughout various head impulses are shown.

Descriptive statistics was done to calculate the mean and the standard deviation for VOR gain for both the groups and the mean and standard deviations of diabetic and non diabetic groups are shown in Table 4.9.

Table: 4.9.

Mean and standard deviation (SD) of mean VOR gain of all the six semicircular canals in non diabetic and diabetic group.

Planes	**N**	**Non diabetic**		**N**	**Diabetic**	
		Mean	SD		Mean	SD
Right Horizontal	28	1.01	1.97	28	0.91	0.24
Left Horizontal	28	0.89	0.07	28	0.86	0.13
Right Anterior	28	0.79	0.17	28	0.71	0.23
Left Anterior	28	0.71	0.17	28	0.63	0.25
Right Posterior	28	0.77	0.14	28	0.66	0.16
Left Posterior	28	0.79	0.16	28	0.76	0.14

It can be seen from the table 4.9 that, in the diabetic group, the mean values of right anterior, left anterior and right posterior semicircular canals were less than VOR gain values of all the six semicircular canals in non diabetic group. Also the mean VOR gain values were then compared for diabetic individuals and non diabetic individuals.

Mean VOR gain of all the six semicircular canals for both the groups are shown in figure 4.16. And asymmetry ratio of the entire 3 planes i.e. Lateral plane, Right

anterior-left posterior plane and left anterior-right posterior plane is shown in figure 4.17 for both the groups.

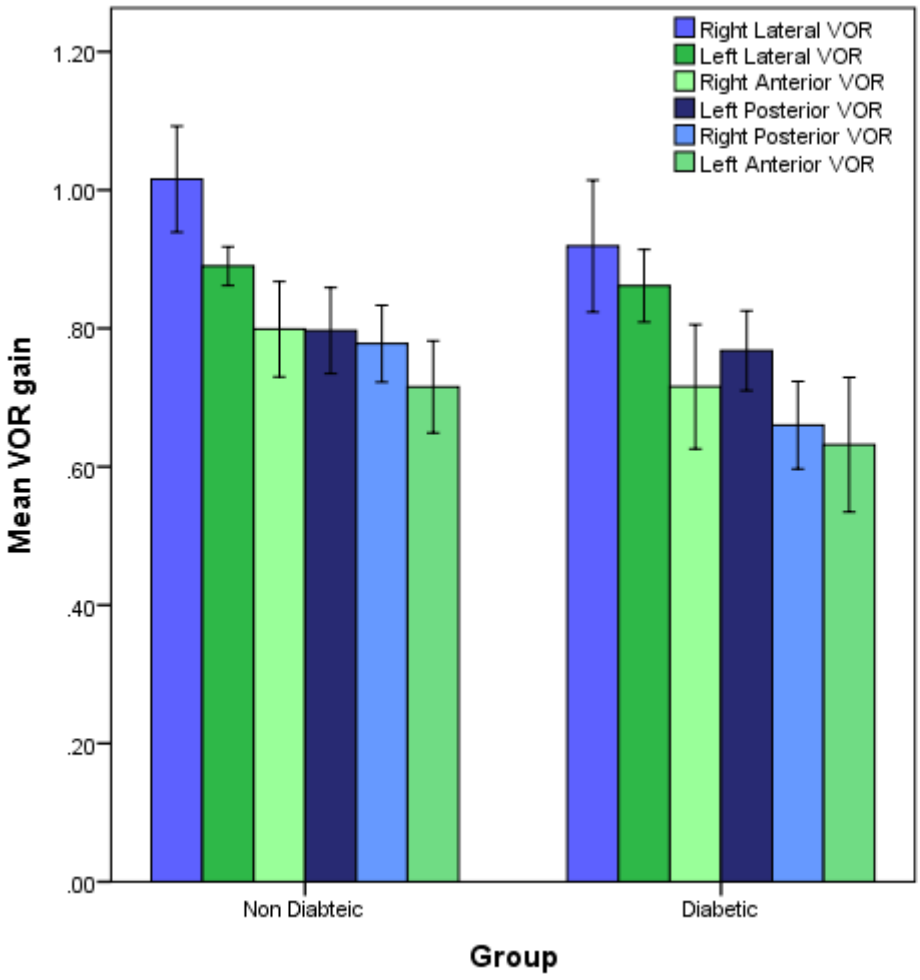

Figure 4.16. Mean VOR gain in all the six semicircular canals in non diabetic group and diabetic group.

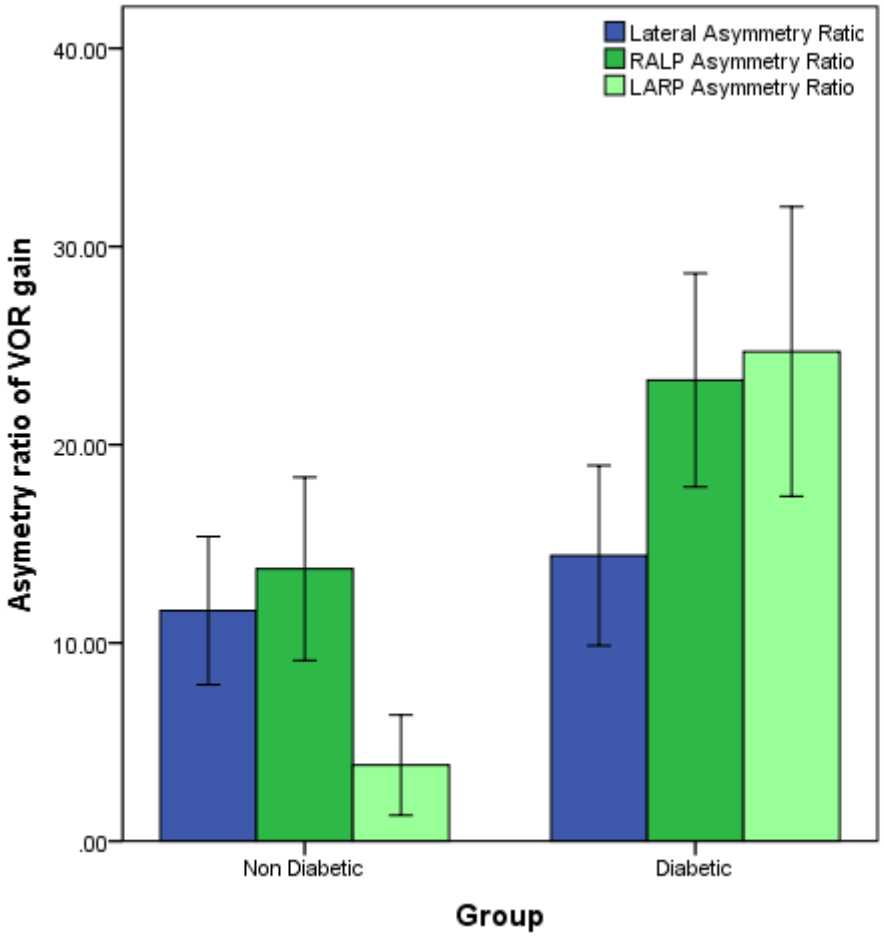

*Figure 4.17.*Asymmetry ratio of mean VOR gain in all the 3 planes of semicircular canals in non diabetic group and diabetic group.

Independent t-test was performed for further analysis of diabetic group and non diabetic group. Results of this test showed that, there was no significant difference in the mean VOR gain of right lateral [t(54)=1.60,p= 0.11], left lateral [t(54)=0.98,p=0.32], lateral canals asymmetry ratio [t(52)=0.97,p=0.33], right anterior [t(54)=1.50,p=0.13], left posterior [t(54)=0.69,p=0.48], left anterior [t(54)=1.45,p=0.15], right posterior [t(54)=2.89,p=0.06] canals and asymmetry ratio of right anterior-left posterior [t(54)=2.75,p=0.08]. However, left anterior-right posterior planes [t(53)=5.70,p=0.00]showed significant difference in diabetic and non diabetic group.

d. Correlation of VEMP latency and amplitude with duration of diabetes mellitus

Latency and amplitude of the cVEMP and oVEMP were correlated with the duration of diabetes in individuals in diabetic group individuals. Spearman's Rank-Order correlation revealed no correlation between p1 latency of cVEMP for diabetic group with duration of diabetes mellitus (r_s= 0.18; p= 0.51), n1 latency of cVEMP for diabetic group with duration of diabetes mellitus (r_s= 0.10; p= 0.71), and p1n1 peak-to-peak-amplitude of cVEMP with duration of diabetes (r_s= 0.06; p= 0.80).

Spearman's Rank- Order correlation revealed no correlation between n1 latency of oVEMP for diabetic individuals with duration of diabetes (r_s= 0.11; p= 0.76), p1 latency of oVEMP in diabetic individuals with duration of diabetes mellitus (r_s= 0.31; p= 0.93), n2 latency of oVEMP in diabetic individuals with duration of diabetes mellitus (r_s= 0.06; p= 0.93), p1n1 amplitude complex in diabetic individuals with duration of diabetes mellitus (r_s= 0.31; p= 0.34) and p1n2 amplitude complex in diabetic individuals with duration of diabetes mellitus (r_s= 0.36; p= 0.26).

In summary there was no correlation in the vestibular evoked myogenic potentials and duration of diabetes mellitus.

e. Correlation between vHIT and duration of diabetes mellitus

Spearman's rank order correlation revealed no correlation between VOR gain of right lateral canal with duration of diabetes mellitus (r_s= 0.24; p= 0.21), VOR gain of left lateral canal with duration of diabetes mellitus (r_s=0.22; p= 0.24), VOR gain of right anterior canal with duration of diabetes mellitus (r_s=0.13; p= 0.49), VOR gain of left posterior canal with duration of diabetes mellitus (r_s= 0.03;p= 0.86), VOR gain of right posterior canal with duration of diabetes mellitus (r_s= 0.33; p= 0.08) and VOR gain of left anterior canal with duration of diabetes mellitus (r_s= 0.05; p= 0.78).

Spearman's rank order correlation revealed no correlation between asymmetry ratio of lateral VOR gain and duration of diabetes mellitus (r_s= 0.22; p= 0.25), asymmetry ration of right anterior- left posterior VOR gain and duration of diabetes mellitus (r_s= 0.19; p= 0.31) and asymmetry ration of left anterior-right posterior VOR gain and duration of diabetes mellitus.

f. Association between vestibular evoked myogenic potentials and degree of hearing loss

To find the association of cVEMP and oVEMP test findings and degree of hearing loss in diabetic individuals, chi-square test was performed. Table 4.10 shows chi-square value for the association between cVEMP and degree of hearing loss. Table 4.11 shows chi-square value for the association between oVEMP and degree of hearing loss.

Table 4.10.

Association between cVEMP and degree of hearing loss in diabetes individuals

		Degree of Hearing Loss				Total
		Normal	Minimal	Mild	Moderate	
cVEMP	Present	13	10	1	5	29
	Absent	3	3	3	18	27
	Total	16	13	4	23	56

*P<0.05 (Chi-Square test)

Table 4.11.

Association between oVEMP and degree of hearing loss in diabetes individuals.

		Degree of Hearing Loss				Total
		Normal	Minimal	Mild	Moderate	
oVEMP	Present	8	8	0	3	19
	Absent	8	5	4	20	37
	Total	16	13	4	23	56

*P<0.05 (Chi-Square test)

To summarize, the prevalence of cVEMP and oVEMP was lesser in individuals with diabetes compared to non diabetic. Also cVEMP, in individuals with diabetes for whom the responses were present, the amplitude was significantly lesser compared to the non diabetic individuals. In vHIT only the left lateral-right posterior plane showed VOR gain for diabetic individuals were lesser than the non diabetic individuals. Also there was no correlation between the VEMP, vHIT parameters and the duration of the diabetes mellitus. However an association was seen between VEMP and the degree of hearing loss.

Chapter V

DISCUSSION

5.1. Vestibular evoked myogenic potentials

cVEMP was present in 80.3% non diabetic individuals and only in 51.78% diabetic individuals. In cVEMP, there was no significant difference in the latencies of p1 & n1 between non diabetic and diabetic individuals. However, there was significant difference seen in the p1n1 amplitude complex of non diabetic individuals and diabetic individuals. oVEMP was present in 58.91% non diabetic individuals and 33.92% of diabetic individuals. There was no significant difference seen in the latencies of n1, p1 & n2 in non diabetic and diabetic individuals. Also there was no significant difference in the p1n1 & p1n2 amplitude complex in non diabetic and diabetic individuals.

Several studies reported vestibular dysfunctioning in individuals with diabetes. Ward et al. (2015) reported that about 50 % of the diabetic individuals had absent oVEMP and cVEMP responses. D'Silva et al. (2017) reported that, 28.9% individuals with diabetes had absent or abnormal cVEMP responses. Abnormal or absent oVEMP were seen in 51.51% diabetic individuals due to increased amount of HbA1c levels. In the present study it can be concluded that absent of oVEMP and cVEMP responses could be due to higher amount and HbA1c cells and causing dysfunctioning of vestibular system.

Perez et al. (2001) reported reduction in the amplitude of p1n1 and prolongation of first wave of VEMP in diabetic individuals due to the functional impairment of vestibular end organ which could occur because of the accumulation of lipid droplets in the subneuroepithelial connective tissues of the vestibular end organs. Klagenberg et al. (2007) reported that in diabetic individuals 60% of changes occurs in the peripheral vestibular system compared to auditory system. Kamali et al. (2013) reported that, the

latencies of p13 showed significant difference between the diabetic group with polyneuropathy, diabetes without polyneuropathy and normal healthy individuals could be indicative of retrolabyrinthine pathology whereas, latency of n23 did not show any significant difference between those groups.

Ward et al. (2015) reported significant reduction in the cVEMP peak-to-peak amplitude and oVEMP amplitude were also reduced in diabetes individuals. Kalkan et al. (2018) reported reduction in the peak-to-peak amplitude of cVEMP (p13-n21) and oVEMP (n10-p15) in diabetic individuals than the normal healthy individuals. Myers and Ross (1987) reported that there was an overproduction of extracellular matrix in the diabetic animals compared to non diabetic animals and this led to degeneration of scattered type I hair cells in the saccule of diabetic animals and saccule is more vulnerable to diabetes.

Konukseven et al. (2015) reported that, cVEMP and oVEMP, p1 and n1 latencies were prolonged in diabetic individuals compared to prediabetic and control group due to pathogenesis which can involve degeneration due to sensorial or motor polyneuropathies, which frequently results of type 2 diabetes mellitus. Ibraheem, Hassaan and Mousa (2017) reported dysfunctioning of vestibular system occurs more in type 2 diabetes mellitus and in insulin treated diabetes compared to orally treated diabetes. Tavakoli et al. (2014) reported the significant difference in the cVEMP parameters of diabetic individuals and the control group due to involvement of central pathway and vestibular end organ.

Contrary to above studies, Bektas et al. (2008) reported that there was no significant difference in the p1, n1 latencies and p1n1 amplitude of cVEMP in diabetic individuals with or without polyneuropathy possibly their range of range of latencies were quiet small. D'Silva et al. (2017) reported abnormal cVEMP responses in diabetes

individuals than the normal healthy control group but there was no significant difference in the cVEMP latencies between diabetic individuals and in healthy individuals. However, there was significant prolongation of n10 latencies of oVEMP in diabetic individuals compared to normal healthy control group. Omar et al. (2018) found no significant difference in p13 n23 latencies and peak-to-peak amplitude of cVEMP and also in oVEMP n10 latency and peak-to-base amplitude in non insulin dependent diabetes mellitus individuals and healthy control group did not show any significant difference. Gawron et al. (2002) reported that diabetes mellitus can affect the vestibular system but mostly it creates disturbances in the central part.

In the present study cVEMP and oVEMP were absent in many of the individuals with diabetes mellitus compared to non diabetic individuals. This suggests a dysfunction of the peripheral vestibular structures (utricle and saccule) in individuals with diabetes. Also, cVEMP was more affected compared to the oVEMP suggestive of more saccular dysfunction in diabetes compared to non diabetes.

5.2. vHIT in diabetes mellitus*:*

In the present study there was no significant difference was seen in VOR gain of all the six semicircular canals of non diabetic individuals and diabetic individuals. Also the asymmetry ratio of VOR gain in lateral plane and in right anterior-left posterior plane of non diabetic individuals and diabetic individuals showed no significant difference. However, the significant difference was noted in the asymmetry ratio of VOR gain in left anterior-right posterior plane of non diabetic and diabetic individuals.

Kalkan et al. (2018) found that there was no significant difference in the VOR gain values of diabetic individuals and normal healthy control groups. Nicholson et al. (2002) also reported no significant difference in the VOR gain of diabetic and non diabetic individuals but there was significant reduction in the phase re velocity in the

diabetic cases compared to healthy control group and have increased postural instability due to vestibular system dysfunctioning. Cardenas-Robledo et al. (2016) reported decreased VOR gain in individuals with maternally-inherited diabetes mellitus and deafened due to bilateral peripheral vestibulopathy led to oscillopsia during head movement and decreased dynamic visual acuity as a factor which caused impaired vision. Omar et al. (2018) reported no significant difference in VOR gain of all the six semicircular in noninsulin dependent diabetes mellitus and VOR gain of all six semicircular canals in healthy control group with absence of overt or covert saccades. Ward et al. (2015) reported that individuals with type 2 diabetes mellitus performed poorly for lateral and superior semicircular canals compared posterior semicircular canals. D'Silva et al. (2015) reported that, occurrence of benign paroxysmal vertigo is more in individuals with diabetes. Rigon et al. (2007) reported that, the perfect functioning of the vestibular system may be impaired in patients affected by the diabetes, even when such individuals do not have complaints.

In this study results indicated, no significant difference in all the six semicircular canals and asymmetry ratio of right anterior-left posterior and lateral semicircular planes. No difference in VOR gain between diabetes and non diabetes individuals could be because of VOR gain compensation. Such VOR gain compensation from central nervous system may lead to a normal VOR gain in individuals with diabetes mellitus.

4.3. Correlation between VEMP parameters and vHIT with duration of diabetes mellitus:

In the present study the results revealed no significant correlation between the VEMP parameters and vHIT with the duration of the diabetes.

Agrawal et al. (2010) found the significant correlation and reported that the dysfunction of vestibular system occurs in diabetes mellitus can occur due to higher level

of serum haemoglobin A_{1c} or due to the longer duration of the diabetes. Gawron et al.(2002) reported that increase in the duration of diabetes mellitus resulted in disturbances in the electronystagmography (ENG) because of hyperglycaemia led to provoke disturbances of the vestibular system mostly in the central part. Konukseven (2015) suggested that longer duration of diabetes mellitus led to chronic neural degeneration in diabetic patients which can have effect on latencies of VEMP. D'Silva et al. (2017) reported did not find any correlation between the oVEMP parameters and the duration of the diabetes and theorized that hyperglycemia might not affect more to superior vestibular nerve and utricle.

Yoda et al. (2011) reported that, individuals with diabetes mellitus have cupular free floating deposits in the semicircular canals compared to normal or control group individuals and also patients having longer duration of diabetes led to have higher chances of benign paroxysmal positional vertigo.

Rajendran, Anandhalakshmi, Mythili and Rao (2011) reported that the duration of diabetes (above or below 10 years) has no effect in the incidence of hearing loss in the diabetic group. Similarly, Panchu (2008) reported no correlation between the duration of diabetes and degree of hearing loss in individuals with diabetes. Also, there is no correlation between the duration of the diabetes and abnormality of auditory brainstem responses (Zehra, Kaya, Gonen, Ilhan, 1999). It has been reported that the duration of diabetes might not be a factor in abnormality of the different tests rather than the uncontrolled levels of the glucose might be a factor in damaging different structures (Panchu, 2008). It is hypothesized that the uncontrolled levels of the glucose might be a factor in damaging of the otolith organs rather than the duration of the diabetes and hence no correlation was obtained between the duration and vestibular test results.

4.5. Association between vestibular evoked myogenic potentials and degree of hearing loss

The results of the study revealed a significant association between VEMP and degree of hearing loss.

Most of the participants in the present study had a minimal hearing loss of less than 30dB HL. Many studies suggested that diabetes causes hearing loss. Several probable mechanisms of hearing loss in cases with diabetes have been proposed: few of them are microangiopathy of the inner ear, neuropathy of the cochlear nerve, a combination of both, outer hair dysfunction and disruption of endolymphatic potential. The tissue effects of diabetes are thought to be related to the polyol pathway, where glucose is reduced to sorbitol. Sorbitol accumulation is implicated in neuropathy by causing a decrease in myo inositol content, abnormal phosphoinositide metabolism and decrease in Na+ K+ ATPase activity (Dennis et al., 2008).

Since the auditory brainstem responses were normal in present study in all the participants in the experimental group, it can be hypothesised that the lesion in individuals who participated for this study might be confined to the cochlear structures. Makishima and Tanaka (1971) have also reported a severe atrophy of the spiral ganglion in the basal and middle turns of the cochlea in diabetic patients with sensorineural hearing loss. Further no correlation between the puretone average and VEMP (cVEMP and oVEMP) results could be due to the fact that the structures involved in processing of the puretone signals and generation of VEMP (cVEMP and oVEMP) are different. It can be hypothesised that the level of glucose might have a differential effect on the two structures i.e. it might affect the vestibular structures more than cochlear structures. However, there are no studies to support the above hypothesis, this could be probable reason. Further studies can prove or reject this hypothesis.

Chapter VI

SUMMARY AND CONCLUSION

The inner ear encompasses hearing organ i.e. cochlea and sensory organs includes otolith organs and semicircular canals. The cochlea helps in hearing and sensory organs helps in balance. The hearing organ and vestibular organs are connected anatomically and situated in the inner ear and functionally enclosed within same membranous labyrinth. Each of the semicircular canal is placed at right angle to each other. Damage to the vestibular system or any pathology related to the vestibular system, can create problems related to the balance. Chronic Diabetes mellitus is one of the causes which can lead to risk of falls and dysfunction of vestibular system.

As mentioned above vestibular system includes various structures. To diagnose those structures there are different tests which can give accurate results about specific structures and these tests must be included during evaluating vestibular system functioning. The tests which can be used: cVEMP to assess saccule, oVEMP to assess utricle and vHIT to assess semicircular canals. These three tests give detail information about overall vestibular system in normal healthy individuals and diabetic individuals. Hence, the aim of the present study was to assess otolith organs and semicircular canals in individuals with diabetes mellitus by using cVEMP, oVEMP and vHIT.

The objectives of the present study are:

1. To study the functioning of utricle in individuals with diabetes mellitus.
2. To evaluate the functioning of saccule in individuals with diabetes mellitus.
3. To assess the functioning of six semicircular canals in individuals with diabetes mellitus.
4. To check the correlation between duration of the disorder and results of 3 tests i.e. cVEMP, oVEMP, & vHIT in individuals with diabetes mellitus.

5. To check the association between VEMP and degree of hearing loss in individuals with diabetes mellitus.

To achieve the aim, the study included two groups. Group I consisted of 28 non diabetic individuals with or without sensorineural hearing within the age range of 35 - 65 years. Group II consisted of 28 diabetic individuals with or without sensorineural hearing loss within age range of 35- 65 years. All the subjects underwent detailed case history, audiometric evaluation, immittance audiometry to rule out middle ear pathology if any, cVEMP, oVEMP and vHIT. The individuals with retrocochlear pathology were excluded from the study.

The recording of cVEMP and oVEMP was done using 500 Hz tone burst stimuli presented at 95 dBnHL. To record the cVEMP, positive electrode was placed on the sternocleidomastoid muscle, negative electrode was placed on the sternoclavicular joint and the ground electrode was placed on the forehead. To record oVEMP, positive electrode was placed 1 cm below the eyes, negative electrode was placed 1 cm below the positive electrode and ground electrode was placed on the forehead. For both the recordings time window of 70 msec including -10 msec pre stimulus time was used along with 5.1/sec repetition rate. Both the cVEMP and oVEMP responses were analyzed. vHIT was done on all the participants included in the study. The client was placed one meter away from the target and head impulses were given in 3 planes; lateral plane, left anterior-right posterior plane and right anterior-left superior plane.

The waveforms of cVEMP, and oVEMP and VOR gain from vHIT were obtained from all the subjects involved in the study. In the cVEMP analysis of p1 and n1 latency and p1n1 peak-to-peak amplitude complex were done. For the oVEMP; n1, p1, n2 latencies and p1n1 and p1n2 amplitude complex were analyzed. VOR gain was calculated for all six semicircular canals and saccades were analyzed for vHIT.

- ❖ Descriptive statistics was done to obtain Mean and standard deviation for the non diabetic and diabetic group for cVEMP, oVEMP and vHIT parameters.
- ❖ Paired sample t-test was performed to compare the latency and amplitude of cVEMP and oVEMP between the two ears.
- ❖ cVEMP, oVEMP and vHIT parameters were compared between non diabetic and diabetic group using non parametric Mann-Whitney U test as the number of samples was different in both the groups.
- ❖ Spearman Correlation test was done to find out a correlation between duration of diabetes with cVEMP, oVEMP and vHIT parameters.
- ❖ Chi-square test was done to see the association between VEMP and degree of hearing loss.

The above statistical analysis revealed following results:

1. **Cervical vestibular myogenic evoked myogenic potentials**

- ❖ cVEMP was present in 45 ears out of 56 ears in non-diabetic individuals and 29 ears out of 56 ears in diabetic individuals.
- ❖ There was no significant difference was seen for latencies and peak-to-peak amplitude of right and left ear in cVEMP for both the groups.
- ❖ There was significant difference in the p1n1 amplitude complex between non diabetic group and diabetic group.
- ❖ There was no significant difference in the latency of p1 and n1 between non-diabetic and diabetic group.
- ❖ There was no correlation between p1,n1 latencies and peak-to-peak amplitude of cVEMP test results with duration of diabetes.
- ❖ There was significant association between the cVEMP results and degree of hearing loss.

2. **Ocular vestibular evoked myogenic potentials:**

- ❖ oVEMP was present in 33 ears out of 56 ears in non-diabetic individuals and 19 ears out of 56 ears in diabetic individuals.
- ❖ There was no significant difference was seen in the n1, p1, n2 latencies and p1n1 and p1n2 amplitude complex between non diabetic individuals and diabetic individuals.
- ❖ There was no significant correlation between oVEMP test results and the duration of diabetes mellitus.
- ❖ There was significant association between the oVEMP and the degree of sensorineural hearing loss.

3. **Video head impulse test**

- ❖ The mean VOR gain was no significant difference found between the non diabetic group and diabetic group in the VOR gain of right lateral, left lateral, lateral canals asymmetry ratio, right anterior, left posterior, left anterior, right posterior canals and asymmetry ratio of right anterior-left posterior.
- ❖ There was significant difference found in left anterior-right posterior plane of non diabetic group and diabetic group.
- ❖ There was no correlation found between vHIT results and the duration of diabetes mellitus.

CONCLUSION

Cervical and ocular vestibular evoked myogenic potentials along with vHIT provide detailed information about saccule, utricle and semicircular canals. Hence, these tests can be used to assess functioning of vestibular structures in different vestibular pathologies. Findings of the present study suggest high prevalence of saccular and utricular pathologies in diabetic individuals as compared to non diabetic individuals. The results also suggest a significant association between cVEMP, oVEMP results and the degree of hearing loss in diabetic individuals. There was no significant correlation between the cVEMP, oVEMP findings and the duration of the diabetes mellitus. There was no significant correlation between the vHIT results and the duration of the diabetes mellitus. There was no significant difference in the VOR gain of all the semicircular canals non diabetic individuals and diabetic individuals. There was no significant difference in the asymmetry ratio of lateral plane and right anterior-left posterior plane however, there was significant difference was seen in the asymmetry ratio of left anterior- right posterior plane between non diabetic group and diabetic group. To conclude, the saccule and the utricle is more affected in individuals with diabetes compared to non-diabetes individuals. The age of the non-Diabetic group individuals was matched with the diabetic individuals; hence the results are not suggestive of any aging effect for the diabetes individuals. The VOR gain was normal in individuals with diabetes which could be suggestive of VOR gain compensation. However, the VOR gain asymmetry ratio was more in Diabetes individuals which could be suggestive of some abnormality between right and the left vestibular system. It is recommended to assess the vestibular system in all the individuals with diabetes.

Implications of the study:

The study provides knowledge about the functioning of otolith organs and semicircular canals in individuals with diabetes mellitus. Such knowledge about the vestibular damage in individuals with diabetes will help the clinicians in making a vestibular rehabilitation plan for individuals with diabetes.

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