Measurement of Ocular tilt using Subjective visual vertical test in Individuals with Sensorineural Hearing loss

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This dissertation is submitted as a part of fulfilment

for the Degree in master of science in Audiology

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CERTIFICATE

This is to certify that this dissertation entitled '**Measurement of Ocular tilt using Subjective visual vertical test in Individuals with Sensorineural Hearing loss'** is the bonafide work submitted in part of fulfilment for the Degree in master of science in Audiology of the student with registration No. **18AUD003**. 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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CERTIFICATE

This is to certify that this dissertation entitled '**Measurement of Ocular tilt using Subjective visual vertical test in Individuals with Sensorineural Hearing loss'** has been prepared under my supervision and guidance. It is also certified that it has not been submitted earlier to any other university for the award of any other diploma or degree.

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DECLARATION

This is to certify master's dissertation entitled **'Measurement of Ocular tilt using Subjective visual vertical test in Individuals with Sensorineural Hearing loss'** is result of my own study under the guidance of Dr Sujeet K Sinha, Associate Professor in Audiology, department of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other diploma or degree.

Mysuru **Registration No. 18AUD003**

July 2020

Dedicated to my parents, brother,

friends and Sujeet sir my guide for

their constant everlasting support

for pursuing the degree.

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Abstract

The subjective visual vertical (SVV) is a perception often impaired in patients with neurologic disorders and is considered as a sensitive tool to detect otolith dysfunctions. SVV can either assessed using Virtual system or Bucket test. An extensive review of literature suggests that SVV has a great application in the assessment of utricular function and found to be having a great diagnostic value in cases like BPPV, Meniere's Disease, viral Labyrinthitis, Vestibular neuritis, SSNHL, Vestibular migraine etc. limited literature which examine the correlation between the Virtual system and Bucket test for the assessment of verticality led to the present study which is aimed at measuring and comparing the ocular tilt using the virtual system and bucket test in individuals with unilateral sensorineural hearing loss or individuals with bilateral asymmetric sensorineural hearing loss. The study consisted of 11 asymmetrical SNHL and 15 normal hearing individual. The SVV was measured using both virtual system and Bucket test in 3 head positions. The results show that the SNHL population have relatively higher ocular tilt when compared to normal hearing individual. Study also reveals that there is a correlation between both tests in the assessment of ocular tilt as there is no significant difference in the ocular tilt value between both the tests. Thus the study concludes that there is a utricular dysfunction in individuals with asymmetrical sensorineural hearing loss as they possessed a higher ocular tilt when compared to the normal hearing individuals and either of the test can be used to assess otolith function.

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Chapter-I

INTRODUCTION

The inner ear consists of auditory and vestibular structures responsible for hearing and balance functions. The causative factors of sensory neural hearing loss can also accompany vestibular impairments because both the systems share the same membranous labyrinth. Any damage to the inner ear can cause damage to both the cochlear and the vestibular system. In the vestibular system it can lead to an impairment of either semi-circular canals or the otolith organs or both. The otolith organ, utricle helps in sensing linear forward and backward movements in the horizontal linear acceleration of the body whereas, saccule helps in vertical linear acceleration of the body.

Ocular tilt is the symptom of skew deviation which is the presence of vertical misalignment of eye caused by damage to the otolith organs. The ocular tilt reaction emerges from compensation for an injury to the utricle or the central vestibular system (Halmagyi, Gresty, & Gibson, 1979). It is thus can be considered as a combination of vestibulo-ocular and vestibule-spinal anomaly which is resulting in the vertical misalignment of the eyes.

Subjective visual vertical (SVV) is the ability of an individual to perceive the verticality in space which is achieved by an intact visual and vestibular system. SVV can be tested using the Bucket test (Zwergal, Rettinger, Frenzel, Dieterich & Strupp, 2009). During the SVV testing, an individual is handed with a bucket inside which a bright vertical strip is placed, the individual is instructed to place their head inside the bucket and align the position of the strip in their perceived vertical position, and the bucket will be handed to the subject at different position of the vertical strip. Perceived deviation of greater than 3º deviation from the true vertical is considered as abnormal result (Halfstorm, Fransson, Karlberg, & Magnusson,2004). Another system for testing SVV is the virtual system known as "virtual SVV system" which consists of light occluding goggles with a digital luminous bar visible to the patient inside the goggle. The patient uses handle removed control to rotate the luminous bar to a position that a subject perceives as a true vertical. The gyroscope inside the goggle allows for monitoring of the angle of the patient's head during testing the software then will be able to determine the angle of the patient's head during testing as well as the deviation of the luminous bar from the true vertical during testing.

1.1 Need for the study

1.1.1 Need for vestibular studies in individuals with Sensorineural hearing loss

There is a great association between vestibular or balance disorders in sensorineural hearing loss as vestibule and cochlea shares a continuous membranous labyrinth and also has a similar receptor cell (Zhou, Wu, & Wang, 2016). Thus the damage to the cochlea can lead to damage to the vestibular organ. Disorder of inner ear may lead to a different type of manifestation including, spatial disorientation, vertigo, blur vision, and hearing impairment. Considering the diversity of clinical symptoms associated with hearing loss with otolith organ dysfunction, the objective means of testing the function of otolith organs should be recommended for the hearing-impaired patient. There are many reports of vestibular and balance dysfunction in hearing-impaired children, as it was reported that 70% of children persisting with SNHL have vestibular system disorders (Santos, Venosa, &Sampaio, 2015). A significant number of children with sensorineural hearing loss experienced vertigo after cochlear implant surgery (Steenerson, Cronin, & Gary, 2001).

The prevalence of vestibular related problems in SNHL individuals differs across studies and age groups. A study by (Pajor, Gryczyński, Łukomski, &Józefowicz-Korczyńska, 2002) reported that 50% of the individuals with sensorineural hearing loss complain of vertigo and 30% of them reported of dizziness. The prevalence of vestibular dysfunction in children with severe to profound hearing loss was found to be 18.75% (Wolter.et al. 2016). The vestibular symptoms such as difficulty in balancing among the individuals with unilateral sensorineural hearing loss (Schunknecht 1993; Volker & Chole 2010) has also been reported. Hence there is a need for studying vestibular function in individuals with sensorineural hearing loss.

1.1.2 Need for studying subjective visual vertical test (SVV) in individuals with unilateral Sensorineural hearing loss

SVV is a test that is simple and easy to administer and provides a valuable contribution to the assessment of peripheral vestibular function. SVV was found to be affected in 69.4% of vestibular neuritis patients and 26.3% in sudden sensorineural hearing loss individuals (Ogawa et. al 2012). Kim, and Kim, (2012) reported abnormal SVV in 78% of the Vestibular neuritis individuals. Due to the high prevalence of balance problems in unilateral sensorineural hearing loss individuals, it can result in peripheral vestibular pathology like affecting otolith organs which can disturb the hearing impaired individuals in perceiving verticality However, there is a dearth of studies in SVV in individuals with unilateral sensorineural hearing loss, hence there is a need to study SVV in individual with Sensorineural hearing loss.

1.2 Aim of the Study

The aim of the present study was to measure and compare the ocular tilt using the virtual system and bucket test in individuals with unilateral sensorineural hearing loss or individuals with bilateral asymmetric sensorineural hearing loss.

1.3 Objectives of the study

1. To find out the ocular tilt using the Virtual system in the individual unilateral sensorineural hearing loss or individuals with bilateral asymmetric sensorineural hearing loss.
2. To find out the ocular tilt using Bucket Test in adults with unilateral sensorineural hearing loss or individuals with bilateral asymmetric sensorineural hearing loss.

Chapter II

REVIEW OF LITERATURE

2.1 Clinical applications of the subjective visual vertical test in benign paroxysmal positional vertigo

Subjective visual vertical was reported to be abnormal in individuals with BPPV. Chetana, & Jayesh, (2015) administered SVV in 42 individuals with BPPV in which 36 had unilateral BPPV of posterior semi-circular canal and 6 had lateral SCC involvement. Among 42 individuals with BPPV, 30 patients had abnormal SVV to the same side, four to opposite side and in eight patients it was normal. Thus author concluded that SVV is a useful measure to assess the utricular dysfunction in individuals with BPPV.

Subjective visual vertical was found to be affected and tilted towards the affected side in individuals with BPPV. Sapountzi, Vital and Psillas (2017) administered SVV in 40 individuals diagnosed with BPPV. Authors reported abnormal SVV in individuals with BPPV which was increased to the affected side and the mean SVV was 5.75º which was statistically significant when compared to the mean SVV of the control group (0º ± 2º). Authors concluded SVV can measure the affected labyrinth at the time of diagnosis showing the deviation towards the affected side.

SVV has been found to be effective in measuring the utricular function. It has been reported that in individuals with BPPV post Halpike and Semont maneuvers, there is a significant change in SVV value. Gall, Ireland, & Robertson, (1999). administered SVV in sixteen individuals with BPPV and in 16 individuals with non BPPV. The results revealed a significant difference in SVV values in 14 out of 16 individuals with BPPV when compared to the control group. The authors concluded that SVV can be used as a tool for the assessment of post rehabilitation of BPPV.

Subjective visual vertical test has been reported to be abnormal in individuals with BPPV and also has been reported that the findings improved after administration of repositioning maneuver. Faralli, Lapenna, D'Ascanio, Cipriani, & Ricci, (2017) administered SVV on 30 individuals with BPPV at three stages- during the diagnosis of the disorder, after administering the repositioning maneuver and 7 days after the repositioning maneuver. The SVV was recorded at 0-degree head tilt. The SVV test was affected during the first stage and improved after administering the repositioning maneuver and improved in 23 individuals with BPPV after the second stage of testing. The authors concluded that the SVV has predictive value in the prognosis of BPPV.

2.2 Clinical applications of the subjective visual vertical test in sudden sensorineural hearing loss

In individuals with sudden sensorineural hearing loss SVV has been reported to be abnormal and SVV has been found to be tilted towards the affected side. Vibert, Hausler, Safran and Koemer (1995) included a female in this study who was suffering from acute right peripheral cochlea-vestibular loss associated with a marked vertical Diplopia. Otoneurological examination showed profound deafness and absence of nystagmic response to caloric and pendular rotatory test in the right ear, and the tilt of SVV was recorded to the affected side which was the pathological side. The authors concluded that tilt of SVV was a sign of sudden idiopathic vestibular lesions.

Perception of subjective visual vertical was found to be affected in individuals with sudden sensorineural hearing loss. Ogawa et.al (2012) administered SVV on 80 individuals with sudden sensorineural hearing loss. The results of the study revealed abnormal SVV in 26.3% of individuals with sudden sensorineural hearing loss. The authors concluded that SVV can be found to be affected in individuals with sudden sensorineural hearing loss which will depend upon the site or involvement of the vestibular nerve.

However, it has been reported that SVV abnormality is lesser in individuals with sudden sensorineural hearing loss compared to the vestibular neuritis. Kim, Na, Park, & Shin, (2013). tested 30 individuals with SSNHL and Vestibular neuritis. The results of the study showed that only 10% of individual with sudden sensorineural hearing loss had abnormal SVV but SVV test showed abnormal results in 78% of individuals with vestibular neuritis. The authors concluded that abnormal SVV are less frequent in individual with sudden sensorineural hearing loss compared to vestibular neuritis.

2.3 Clinical applications of the subjective visual vertical test in Meniere's disease

Individuals with Meniere's disease show abnormal Subjective visual vertical and abnormal subjective visual horizontal test findings. Pagarkar, Bamiou, Ridout, & Luxon, (2008) examined the relationship between the direction of deviation of the linear marker (preset angle) and measured subjective visual vertical and subjective visual horizontal values in 10 subjects with unilateral Meniere's disease. 5 out of 10 participants (50%) had an abnormal mean subjective visual vertical and subjective visual horizontal value. The authors concluded that the perception of vertical orientation and horizontal orientation is affected in 50% of the participants with Meniere's disease.

Most of the individuals suffering from Meniere's disease have reported abnormal subjective visual vertical which was found to be tilted towards the affected side. Kumagami et.al (2009) tested 22 individuals with unilateral Meniere's Disease.

The results of the study revealed abnormal tilt on SVV in 14 individuals with Meniere's Disease (63.6 %). The authors also reported that in 12 out of 14 individuals with Meniere's disease, the abnormal tilt returned to normal side within a few days after the acute attack. The authors concluded that otolith dysfunction occurs in acute attacks in a considerable number of patients with Meniere's disease. SVV can be utilized as a good tool for the evaluation of otolith dysfunction at acute attacks in patients with Meniere's disease.

Ocular tilt has been reported to be abnormal in individuals with Meniere's disease Chetana, & Jayesh, (2015) administered SVV test on 11 patients with Meniere's Disease. The results revealed abnormal values of SVV in 6 subjects with Meniere's disease. Three participant showed deviation towards the same side or affected side and one of them showed deviation towards the opposite side or unaffected side.

Patients with Meniere's disease have reported difficulty in perception of verticality when SVV. Fard, Yazdani, Rezazadeh, Alborzi, & Bagheban, (2017).

included 32 individuals with unilateral definite Meniere's Disease and 32 normal individuals with no history of vestibular problem with normal hearing. The authors administered SVV test and found that there was no significant difference between the mean SVV in the normal group and mean SVV in the healthy side of the patients group but significant difference was observed between the mean SVV in the normal group and the mean SVV in the affected side of the patient group. All the individuals with Meniere's disease showed deviation towards the effect side in SVV test. This study concludes that SVV can be used to assess the utricular functioning in individuals with Meniere's disease

2.4 Clinical applications of the subjective visual vertical test Vestibular neuritis

Most of the individuals with vestibular neuritis show deviation of SVV towards the affected side. Bohmer and Rickenmann (1995) measured subjective visual vertical in 25 normal subjects with no vestibular problem or history of any, with bilateral normal hearing sensitivity and results were compared to SVV administered on 73 patients with various peripheral disorders. The results showed significant deviation of SVV towards the affected ear in 100% of the individuals with vestibular nerve section and in 89% of patients with vestibular neuritis and in 0% of the patient with BPPV.

SVV has been reported to be a better tool for testing otolith function in vestibular neuritis individuals, which is significantly affected in these cases. Vibert, & Safran, (1999). measured SVV in 38 patients suffering from vestibular neuritis . The authors reported that SVV was tilted by more than 4degree in 42% of individuals with vestibular neuritis towards the affected side, which concludes that SVV might represent the complementary clinical examination tool for the evaluation of otolith function in peripheral vestibular lesion.

It has been also reported that SVV has a good correlation with clinical improvement of dizziness symptoms in individuals with Vestibular neuritis. Noh and Chae (2007) studied 62 subjects with unilateral vestibular neuritis using SVV test. SVV test was administered during the acute period and sequentially followed during the recovery period. The results revealed abnormal tilt on either side and the range of abnormal tilt improved as the dizziness symptoms improved. The author concluded that SVV correlated with clinical improvement of dizziness symptoms in vestibular neuritis.

It was also found that SVV can be used as a tool for evaluation of clinical manifestation of unilateral Vestibular neuritis. Min et al. (2007) evaluated 35 subjects with unilateral vestibular neuritis using Subjective visual vertical and Subjective visual horizontal in acute period and 4 weeks after rehabilitation. The results showed that SVV was deviated to the lesion side and the mean deviation was 3.51 degrees. They also found that after rehabilitation the deviation improved with the mean of 1.35 degrees. The authors concluded that Subjective visual vertical test would be a useful tool for evaluation of clinical condition of unilateral vestibular neuritis.

Ogawa et. al (2012) performed the SVV test in 32 individuals with vestibular neuritis in which results showed that, SVV wear abnormal in 69.4 % of individuals with vestibular neuritis and they concluded that vestibular neuritis patients showed higher rate of abnormal SVV, it is speculated that the superior vestibular nerve function may affect the SVV tilt, although the inferior vestibular nerve function may also have an effect.

García, and Jáuregui-Renaud (2003) administered SVV on 10 patients with vestibular neuritis and compared with a control group which include 31 normal individual with no history of any vestibular symptoms the testing occurred in 4 weeks of follow-up that is testing 1 person for four times, the mean visual vertical tilt was 8.4 degrees (± 2.4 °) at the first evaluation and no patient had deviation of less than 2 °, and after a follow-up of two weeks again visual vertical was assessed the mean visual vertical tilt was 3.2 degree (± 1.6 degree), and till the last follow-up the mean visual vertical tilt was 1.4 °(±0.7 °) and all the healthy subjects showed a mean deviation of 0.4° (± 0.5°) at both the evaluation. The authors concluded that repeated measurement of SVV can serve as a useful tool to predict the prognosis in the follow-up patients with acute vestibular neuritis.

Most of the individuals with vestibular neuritis have reported abnormal perception of verticality in subjective visual vertical. Chetana, & Jayesh, (2015) administered SVV test on 23 individuals with vestibular neuritis, in which 19 had abnormal deviation of SVV at first visit, and 4 did not show any deviation in which 85% of patients with abnormal SVV showed deviation to same side as hypoactive labyrinth. Authors concluded that SVV can be used as a good tool to assess the vestibular functioning in individuals with vestibular neuritis.

As SVH and SVV is used to assess otolith dysfunction and ipsilateral deviation of SVV and SVH in unilateral vestibular dysfunction is well known, and which was found to be abnormal in patients suffering from vestibular neuritis. Min et.al (2007) did a study on 35 individuals with unilateral vestibular neuritis where investigated, SVV and SVH was assessed during the acute period and the results showed that SVH and SVV was deviated towards the ipsilateral side in 94% and 80% respectively the mean SVV was between 3.51°± 2.49°degree and this concluded that in unilateral vestibular neuritis SVV and SVH showed significant deviation, thus this instrument can be clinically applied not only for assessing subjective dizziness but also for assessing clinical aspect of improvement.

2.5 Clinical applications of the subjective visual vertical test Viral Labyrinthitis

Cases with vestibular labyrinthitis showed that, SVV when assessed, the perception of verticality was found to be affected and the values was deviated from the normal values. Vibert and Safran (1999) measured the SVV and defined the influence of the otolith organs in patient suffering from viral labyrinthitis and results revealed that SVV was tilted by greater than 2 degrees in 47% of the population and tilt was deviated towards the affected ear. The finding of the study suggests that otolith function is implicated in the deficit depending on the extent or the location of the peripheral vestibular lesion.

Bucket test has also been found to be a reliable and sensitive test to detect the unilateral utricular pathology. Sun, Zuniga, Davalos-Bichara, Carey, and Agrawal, (2014) of vestibular symptoms. Receiver operating characteristics curve showed that bucket test is more specific than sensitive for utricular dysfunction, and a bucket test SVV score of 2 degrees may maximize diagnostic yield relative to the currently accepted score of 3.

Bucket test was found to be easy to administer and results was also found to be significantly abnormal compared to normal in individuals with peripheral vestibular lesions. Cohen and Sangi-Haghpeykar (2012) included 25 individuals with BPPV and were compared to normal subject, SVV was administered in both normal and affected population and results showed that to some but not all patient responses different from normal subject. This they concluded that all though bucket test will be useful for describing special deficient in patients, this test is not useful for screening people for possible vestibular impairments.

2.6 Clinical applications of the subjective visual vertical test in Sensorineural hearing loss

According to some authors, most of the patients were found to have deviated SVV at pre-operative and post-operative SVV or when SVV was compared with cochlear implant on and with cochlear implant off Dizziness handicapped Inventory was found to be improved. Gavin, Hwang, Wu, Cushing, and Lin (2016) did a study in which they included12 subjects with severe to profound hearing loss, in pre and post cochlear implantation period using subjective visual vertical test(SVV). The authors found that many subjects had deviated SVV at pre-operative and post-operative assessments. However, there was no statistically significant change in pre-operative and post-operative SVV test results. Thus, the authors concluded that cochlear implantation did not influence vestibular or balance function.

It was also found that most of the individual using CI (off condition) has an abnormal tilt in which the direction of tilt was towards the deficit side and when the CI was stimulated the abnormal deviation shifted towards the center. Gnanasegaram, et.al (2016) studied the abnormalities in perception of the vertical plane using static visual vertical test (SVV) in 53 children with sensorineural hearing loss (SNHL) and aimed to determine whether such abnormalities could be resolved with stimulation from the CI. The results showed that abnormal SVV in nearly half of the participants with CIs in the direction of their deficit. However, after stimulation by CI the abnormal deviation shifted towards the center. Thus, the authors suggested that CI stimulation plays a role beyond the auditory system, in particular, for improving vestibular/balance function.

Chapter III

Method

The present study was conducted with the aim of assessing the utricular function using Bucket test and commercially available test subjective visual vertical test (SVV) in individuals with asymmetrical SNHL or unilateral SNHL. To meet the aim of the study, the participants were divided into two groups of subjects with an age range of 18-50years who participated in the study.

Group 1 included 15 individuals with unilateral SNHL or B/L asymmetric SNHL in the age range of 18-50 years.

3.1 Participant selection criteria for Group I

1. Participants had Unilateral or Bilateral asymmetrical SNHL.
2. All the participants had ‘A’ type tympanogram with reflexes present or absent as per the degree of hearing loss.
3. None of the participants had any retrocochlear pathology or as per the ABR.
4. None of the participants had any history of vestibular disease in case history and none of the participants should had obvious vestibular diseases such as Meniere’s diseases, vestibular neuritis, labyrinthitis, etc.

Group 2- included 15 individuals with normal hearing sensitivity in the age range of 18-50 years with no history or presence of any vestibular signs and symptoms.

3.2 Participant selection criteria for group II

1. All the participants had normal hearing sensitivity (≤ 15 dBHL) at octaves from 250 Hz to 8000 Hz for air conduction and from 250 Hz to 4000 Hz for bone conduction.
2. All the participants showed Presence of ‘A’ type Tympanogram with ipsilateral and contralateral reflexes present for both the ears.

3. None of the participants had history of any vestibular symptoms.
4. None of the participants had any history or presence of any neurological problems.

3.3 Testing environment:

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

3.4 Testing Equipment:

1) Calibrated Inventis Piano Plus was used to perform threshold estimation (pure tone audiometry and speech audiometry) for ruling out any hearing loss components in both the groups to meet within inclusion criteria. Calibrated TDH 39 headphones for AC threshold and calibrated B-71 bone vibrator for BC threshold was used.
2) Calibrated GSI Tympstar-Immittance meter was used to measure Tympanometry with a probe tone frequency of 226 Hz. The same equipment was used for measuring ipsilateral as well as contralateral reflexometry at 500, 1000, 2000, and 4000 Hz.
3) Calibrated ILOV6 system was used to measure Otoacoustic emissions.
4) Calibrated IHS (Intelligent Hearing System) Smart EP (3.94 USBez) system was used to administer a click-evoked auditory brainstem response.

3.5 Procedure:

3.5.1 Clinical Case History and Questionnaire Administration

A detailed case history was taken for all the participants in the study regarding the nature and onset of the hearing loss and attacks of vertigo.

3.5.2 Pure tone Audiometry

Using the modified Hughson and Westlake method (Carhart& Jerger,1959), air conduction threshold with the TDH 39 headphones and bone conduction thresholds with a bone vibrator was obtained for octave frequencies from 250 to 8000 Hz and 250 to 4000 Hz respectively to investigate the hearing sensitivity of each participant.

3.5.3 Impedance audiometry

Tympanometry will be done at 226 Hz probe tone and acoustic reflex threshold was elicited for both ipsilateral and contralateral stimulation at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz.

3.5.4 ABR-Site of lesion (SOL):

Participants was seated in a reclining chair and cleaned at both the mastoids (M1, M2) and forehead (Fz) with skin abrasive followed by the vertical electrode placement. Also, intra-electrode impedance and inter-electrode impedance will be maintained < 5 KΩ and < 2 KΩ respectively. It was performed by making participants relaxed with reduced extraneous body movements. The parameters used for click-evoked auditory brainstem responses are given in Table 3.1.

Table 3.1

Protocol for recording auditory brainstem response (SOL).

Parameters	**Target settings**
Stimulus parameters	
Stimulus	Click stimulus
Polarity	Rarefaction
Stimulus intensity	80dBnHL
Repetition rate	11.1Hz &90.1Hz
Acquisition parameters	
Mode	Ipsilateral
Analysis time	10ms
Filter	100-3000 Hz
Electrode montage	Inverting- M1, M2 Non-Inverting- Fpz Ground- Fz
Sweeps	1500
Transducer	Insert ER-3A
No. Of channel	Two

3.5.5 Subjective Visual Vertical test - (Bucket test)

The bucket test required a bucket to be held with the opening perpendicular to the ground while a sitting participant was asked to place his/her face at the bucket opening. He or she was asked to look at the straight line on the inside bottom of the bucket. The participant was instructed to rotate the bucket until the participant indicated that the line inside the bucket is straight vertically. Once the bucket is adjusted to the subject's perceived vertical position, a measurement was taken in degrees from the bucket exterior based on the position of the weighted string on the protractor and this same procedure was done for 3 head positions – at 0º head position, at head tilted 30º to the right and at head tilted 30º to the left. For each of the head position the procedure was repeated five times and the average of five times was recorded.

3.5.6 SVV-Virtual system

The system consists of light-occluding goggles, which displays a luminous bar which was visible to the participant and a controller. The luminous bar will appear in the headset tilted to the right or left at random computer-generated angles. The participant was instructed to adjust the bar's in vertical position using controller buttons, which can be used to rotate the bar right or left. And when the participant judges the luminous bar to be aligned with true vertical. The SVV was done at 0º head position, 30º head tilted to the right, and 30º head tilted to the left. The procedure was recorded five times for each of the head position and average ocular tilt for the five recordings was considered for the analysis.

Data analysis

1. Subjective visual vertical test

Average of perceived vertical angle is calculated at static (0º) and at head tilted 30º right & 30º left.

2. Bucket test

Average of 5 trial is calculated of perceived vertical angle at static (0º) and at head tilted 30º right & 30º left.

Chapter-IV

Results

The present study was conducted to measure and compare the ocular tilt using a virtual system and Bucket test in individuals with unilateral sensorineural hearing loss (SNHL) or bilateral asymmetric (B/L) SNHL. To achieve the aim,11 participants with unilateral SNHL or B/L asymmetric SNHL and 15 participants with normal hearing were employed in the study. All the individuals underwent Bucket test and SVV virtual system testing. To analyze the data, Statistical Package for the Social Science (SPSS) version 20 was used.

4.1 Ocular tilt findings

SVV could be administered for all the participants using both the bucket test as well as the virtual test. Figure 4.1 and 4.2 shows an example of report obtained from the SVV instrument for 0 degree and 30-degree head position

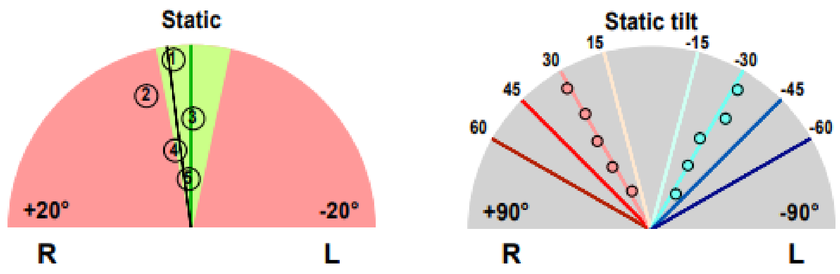

Figure 4.1 Representative figure of ocular tilt at 0 degree and 30-degree head tilt to both sides of an individual with normal hearing.

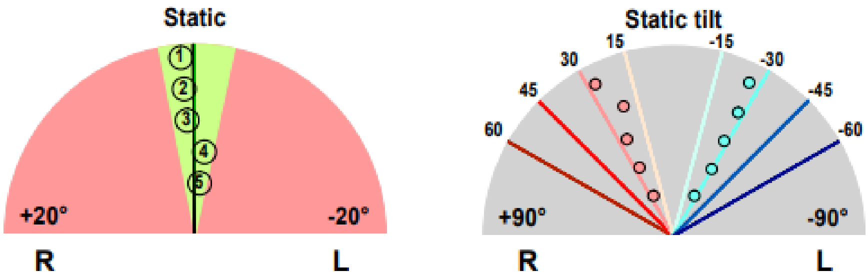

Figure 4.2 Representative figure of ocular tilt at 0 -degree and 30-degree head tilt to both sides of an individual with SNHL.

Descriptive statistics was done to calculate the mean, standard deviation for three different static head positions in both groups. The mean values and the standard deviation for three different static head positions for the normal hearing group and the hearing-impaired are given in Table 4.1.

Table 4.1

Mean ocular tilt of normal-hearing group and SNHL group along with a standard deviation of the virtual system and bucket test at each head in position.

			Mean	*SD*
Virtual system	**0 degree**	**Normal Hearing Individuals**	1.04	0.66
		SNHL	1.67	1.10
	30 degree right	**Normal Hearing Individuals**	1.64	1.46
		SNHL	4.28	2.29
	30 degree left	**Normal Hearing Individuals**	1.62	1.44
		SNHL	3.71	3.44
Bucket test	**0 degree**	**Normal Hearing Individuals**	0.90	0.53
		SNHL	2.49	1.43
	30 degree right	**Normal Hearing Individuals**	1.30	0.71
		SNHL	3.66	1.66
	30 degree left	**Normal Hearing Individuals**	1.25	0.62
		SNHL	4.05	2.27

It can be seen from Table 4.1 that the mean ocular tilt is more for individuals with SNHL when compared to normal hearing individuals irrespective of head positions, virtual system and Bucket test. The same can be seen in figure 4.3 and 4.4

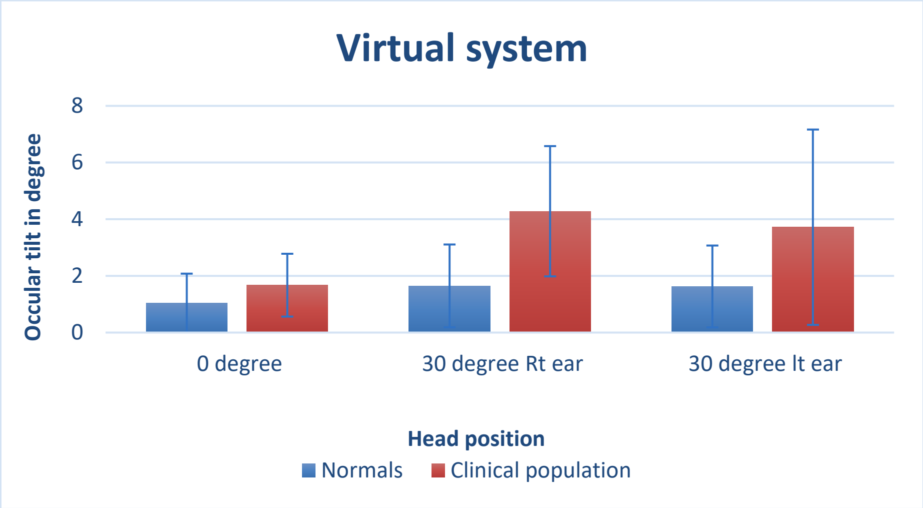

Fig 4.3 Ocular tilt of normal hearing individuals and individuals with SNHL for virtual SVV test

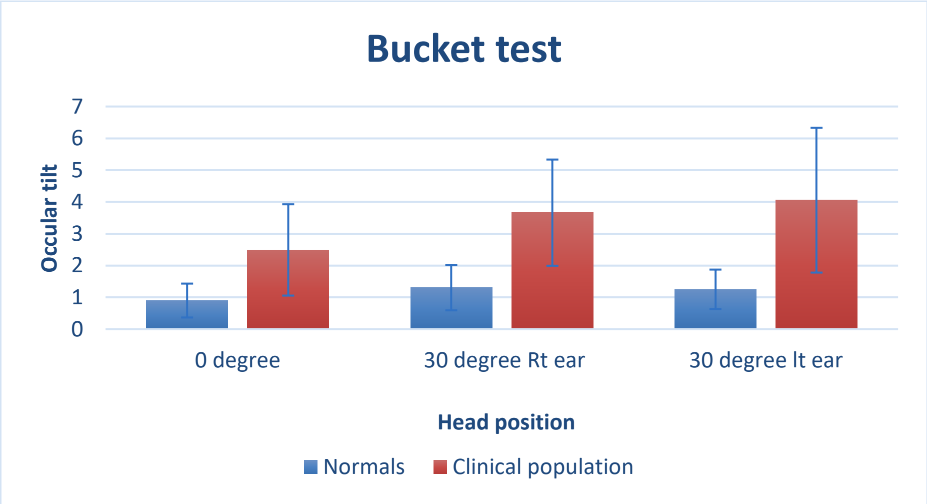

*Fig 4.4*Ocular tilt along with S.D of normal hearing individuals and individuals with SNHL for bucket test

Shapiro-Wilk test was administered to check the whether the data is normally distributed. Shapiro-Wilk test revealed a non-normal distribution of the data ($p<0.05$).

To compare the mean difference of ocular tilt between normal-hearing individuals and in individuals with SNHL for virtual test of SVV, Mann Whitney U was administered for all the three head positions. Mann Whitney U test revealed no significant (U=54.00, p= 0.13) difference between normal hearing individuals and individual with SNHL for 0-degree head position, for 30-degree left head position (U=45.5, p= 0.052) between normal-hearing individual and individuals with SNHL. However, for 30-degree right head position, there was a significant difference (U=28.00, p= 0.005) between normal hearing and individuals and individuals with SNHL for the virtual test of SVV.

Similar comparison of ocular tilt between normal hearing group and in individuals with SNHL group was done for Bucket test using Mann Whitney U test. Results revealed a significant difference for 0-degree head position (U=17.00, p= 0.001) between normal hearing individual and individuals with SNHL, for 30-degree tilt towards right head position (U=10.50, p= 0.00), and for 30-degree tilt towards left head position (U=18.00, p= 0.00).

4.2 Comparison of ocular tilt within each group

To compare the significant differences between mean ocular tilt using two techniques within each group Wilcoxson Sign Rank test was done. Figure 4.3 and figure 4.4 shows mean ocular tilt within each group.

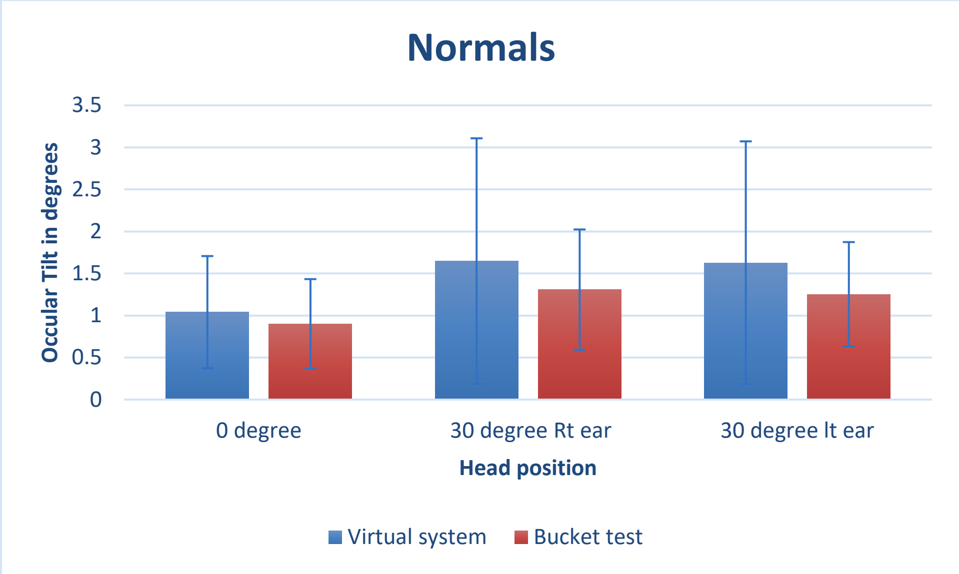

Fig 4.5 Correlation of mean ocular tilt between SVV and Bucket test in control group.

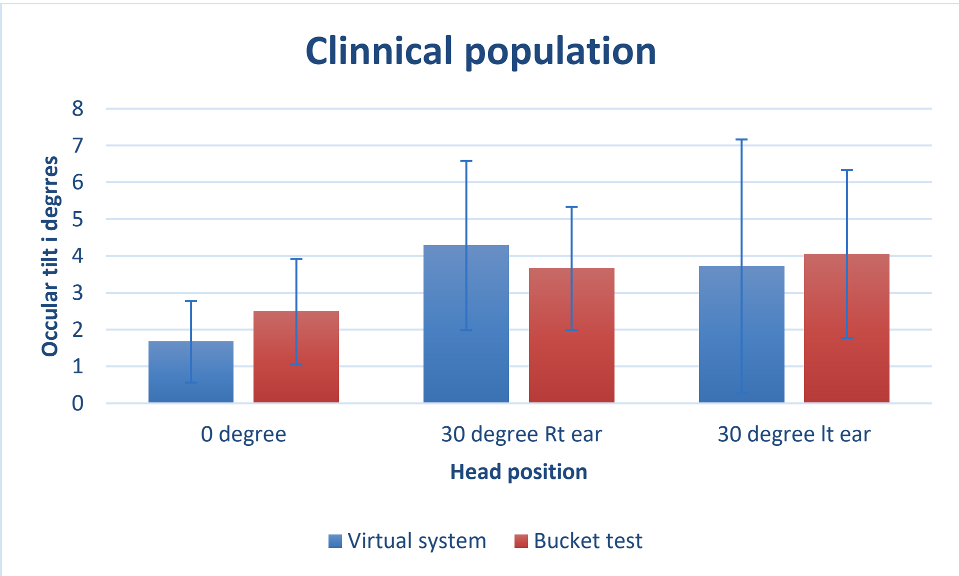

Fig 4.6 Correlation of mean ocular tilt between SVV and Bucket test in SNHL group.

Wilcoxson sign rank test was administered to compare the SVV value of the two test within each group. Wilcoxson sign rank test revealed no significant difference between bucket test and virtual test for the normal hearing individuals at 0-degree head tilt (Z=0.65, p>0.05), for 30-degree head tilt to the right (Z=0.84, p>0.05), and for 30-degree head tilt to the left (Z=0.47, p>0.05). Wilcoxon sign rank test also revealed no significant difference between bucket test and virtual test for individuals with SNHL at 0 degree head tilt (Z=2.39, p>0.05), for 30 degree head tilt to the right (Z=1.69, p>0.05), and for 30 degree head tilt to the left (Z=0.40, p>0.05).

The results of the study reveals that for Bucket test the mean ocular tilt value was significantly different from normal hearing individual when compared with SNHL group for all three head positions, and in virtual system the mean ocular tilt value was significantly different from normal hearing group only for 30-degree right head tilt position but was not significantly different for 0-degree head position and 30-degree left head tilt position. When the between group comparison was done, (Virtual system v/s Bucket test) there was no significant difference found between mean ocular tilt values of virtual system and Bucket test in both normal hearing and SNHL group.

CHAPTER V

DISCUSSION

5.1 Ocular tilt findings

The mean ocular tilt value was calculated for normal hearing individual and in individuals with B/L asymmetrical SNHL and unilateral SNHL, the mean ocular tilt from virtual system in normals were 1.04(SD ±0.66), 1.64(SD ±1.46), and 1.62(SD ±1.44) at 0-degree head position, 30-degree right and 30-degree left head tilt position respectively and in SNHL group the mean ocular tilt values were 1.67(SD ±1.10), 4.28(SD ±2.29), and 3.71(SD ±3.44) at 0-degree head position ,30-degree right and 30-degree left head tilt position respectively. Similarly, mean ocular tilt value from Bucket test in normal hearing individuals were 0.90 (SD ±0.53), 1.30 (SD ±0.71), and 1.25(SD ±0.62) at 0-degree head position, 30-degree right and 30-degree left head tilt position respectively and in SNHL group the mean ocular tilt values were 2.49(SD ±1.43), 3.66 (SD ±1.66), and 4.05 (SD ±2.27)) at 0-degree head position, 30-degree right and 30-degree left head tilt position respectively.

The ocular tilt measured from both Bucket test and virtual system is in agreement with previous study by Michelson, McCaslin, Jacobson, Petrak, English and Hatton (2018) where they have also reported the mean ocular tilt value obtained from Virtual system and Bucket test in normal hearing individuals within 1-2 degree were the mean SVV was 0.48 (SD ± 2.51) and 0.86 (SD ± 3.97) respectively. Ogawa et.al (2012) also reported SVV obtained from virtual system in range from 2.68° to 17.64 degree in Vestibular neuritis individuals. Another study by Fard et.al (2017) where they have measured mean ocular tilt value in individuals with definite Meniere’s disease and concluded that the mean ocular tilt value for the affected side was 2.34° (SD ±1.64) whereas for the normal hearing group it was 0.35 (SD ±0.39).

Similarly using Bucket test Chetana, & Jayesh, (2015). measured SVV in various unilateral vestibular disorder and obtained that mean ocular tilt value ranges from 2-7degree in individuals with vestibular neuritis .The present study is consistent with the previous literature where they have reported abnormal perception of verticality (SVV) in unilateral vestibular loss, and same results has been reflected in this study were there is an abnormal perception of verticality in individuals with B/L asymmetrical SNHL and unilateral SNHL.

Increased ocular tilt in SNHL in a present study can be attributed to the utricular dysfunction because of unequal stimulation of utricle which can occur in individuals with bilateral asymmetrical SNHL and unilateral SNHL. Perception of verticality will be within normal limits if each utricle were equally functional. But in cases where one of the otolith is hypo-functional might be because of less stimulation, the contralateral (good) ear would “push” the Perception of verticality toward the opposite, diseased side (Helling, Schönfeld, Scherer, & Clarke, (2006); Halmagyi & Curthoys, 1999).

5. 2 Comparison of ocular tilt within each group

The mean ocular tilt obtained from virtual system and Bucket test were compared and in both Normal hearing group and SNHL group and results reveals that there was no significant difference found between mean ocular tilt measured with the bucket test and with SVV virtual system.

The results of the study reveal that both SVV and Bucket test are equally efficient in measuring the ocular tilt as there no statistical significant difference found between Bucket test and SVV. Thus both the measurement system is correlated in terms of ocular tilt which suggests that either of the system can be used for the measurement. The present study is in agreement with the study by Michelson, McCaslin, Jacobson, Petrak, English and Hatton (2018) where they have also found no significant difference between Virtual system and Bucket test. However, the authors have suggested to use virtual system for the measurement of ocular tilt which is attributed to the higher test retest reliability and accuracy obtained from virtual SVV system than the Bucket test thus it gives more accurate measurement.

Zwergal et al.(2009) showed that, with the bucket test, the mean deviation from zero was 0.90°. Similarly, in a study done by Vibert, & Safran, (1999) concluded that those with normal vestibular function were able to estimate static SVV within 1.25° to 1.75° of true vertical. The level of precision in the measurement of static SVV was found to be poorer in Bucket test when compared with virtual system. In 0° head position, the findings of present study are reasonably consistent with those of prior investigations whereas in other head position there was no significant difference in the measurement of ovular tilt between virtual system and Bucket test. However, there probably a few or not many studies that empirically examined the correlation between Virtual system and Bucket test.

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CHAPTER VI

SUMMARY AND CONCLUSIONS

The inner ear contains two sensory organs, namely, auditory and vestibular, connected anatomically, and functionally encased within the same membranous labyrinth and also shares common labyrinthine artery and same endolymphatic fluid. Therefore, damage or insult to one of the systems can bring about damage to the other system as well. The vestibular system is broadly categorized into both peripheral and central components. The peripheral system is bilaterally composed of three semi-circular canals (posterior, superior, lateral) and the otolith organs (saccule and utricle). The semi-circular canals detect rotational head movement while the utricle and saccule respond to linear acceleration and gravity, respectively.

The subjective visual vertical is determined by having subjects adjust a visible luminous line in complete darkness to what they consider to be upright, earth vertical. The subjective visual vertical (SVV) is a perception often impaired in patients with neurologic disorders and is considered as a sensitive tool to detect otolithic dysfunctions. SVV can also be tested using the Bucket test, and During the SVV testing using a Bucket test, an individual is handed with a bucket inside which a bright vertical strip is placed, the individual is instructed to place their head inside the bucket and align the position of the strip in their perceived vertical position.

SVV has a great application in the assessment of utricular function and found to be having a great diagnostic value in cases like BPPV, Meniere's Disease, viral Labyrinthitis, Vestibular neuritis, SSNHL, Vestibular migraine etc. which were supported by literature discussed in detail in earlier sections. Since the Bucket test also assesses the perception of verticality, it can also be used to assess the utricular function. Also, the Bucket test being very feasible over the virtual system, it can be used as a supplementary tool for assessment of the utricular system. Even though there is literature that has proved the clinical applications of Bucket test in the assessment of the utricular system, there are a very limited number of studies that examine the correlation between the Virtual system and Bucket test for the assessment of verticality. Keeping the limited literature in mind, a study was carried out to examine the correlation between the virtual system and Bucket test in both clinically normal hearing and SNHL group.

The objectives of the study were.

- To find out the ocular tilt using the Virtual system in the individual unilateral sensorineural hearing loss or individuals with bilateral asymmetric sensorineural hearing loss.
- To find out the ocular tilt using Bucket Test in adults with unilateral sensorineural hearing loss or individuals with bilateral asymmetric sensorineural hearing loss.

In order to achieve the above-mentioned objectives, ocular tilt was measured from fifteen normal-hearing individuals and eleven individuals with SNHL using both virtual systems and Bucket test separately. The ocular tilt was measured for three different head positions (0-degree, 30-degree right tilt, and 30-degree left tilt). The ocular tilt values for all three head positions were of both virtual and Bucket test were fed into SPSS for statistical analysis. Descriptive analysis was done to find out the mean and standard deviation of ocular tilts obtained from the Bucket test and Virtual system for all head positions for both the groups.

The result of descriptive statistics revealed that a higher mean ocular tilt in the SNHL group when compared to the normal hearing group irrespective of head position in both the system. In order to check for the significance in difference of mean ocular tilt values between and within group inferential statistics was administered. Since the data didn't follow the normal distribution, non-parametric tests such as Mann Whitney u and Wilcoxon Test were considered between group (Normal v/s SNHL) and within-group (Virtual system v/s Bucket test) comparison respectively. The results of the inferential statistics reveal that

- There was a significant difference in mean ocular tilt value between SNHL and Normal hearing group for Virtual system in, wherein the mean ocular tilt values were more for SNHL group at 30-degree right head position.
- There was a significant difference in mean ocular tilt value between SNHL and Normal hearing group for Bucket test in all three head positions.
- There was no significant difference between mean ocular tilt value when compared virtual system and Bucket test in both the SNHL and normal hearing groups.

Conclusions

Findings of the present study suggest that SVV obtained from both virtual system and Bucket test provide us same information as there was a significant correlation obtained between both the system. Thus, either of these tests can be used to measure ocular tilt and also to asses utricular function which will help us in identifying and diagnosing various utricular pathologies. Study also reveals that there is a utricular dysfunction in individuals with asymmetrical sensorineural hearing loss as they possessed a higher ocular tilt when compared to the normal hearing individuals.

Implications

- The study provides a better understanding about the utricular function in SNHL group.
- Findings of the study suggest that Bucket test can be used in a clinical set up in the absence of virtual system.
- Study suggests that Bucket test can be used as a supplementary tool in the test battery for the assessment of utricular function.

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