TEST-RETEST RELIABILITY OF VIDEO HEAD IMPULSE TEST IN HEALTHY INDIVIDUALS

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Register No.: 15AUD027

A Dissertation Submitted in Part Fulfilment of Degree of Master of Science

(Audiology)

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May, 2017

CERTIFICATE

This is to certify that this dissertation entitled "**Test-retest reliability of video head impulse test in healthy individuals"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: 15AUD027. 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**"Test-retest reliability of video head impulse test in healthy individuals"**has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Test-retest reliability of video head impulse test in healthy individuals"** is the result of my own study under the guidance of Dr. Niraj Kumar Singh, Lecturer in 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.

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May, 2017

Abstract

Video head impulse test (vHIT) is a relatively new addition to the test battery for assessment of balance dysfunction. Recent reports have shown promising results of vHIT in diagnosis of vestibular pathologies like Meniere's disease, vestibular neuritis, labyrinthitis, vestibular schwanoma, and BPPV. However, for a clinician to completely rely on the results, it is imperative that this test produces similar results each time the test is performed. Nonetheless the studies assessing the test-retest reliability of vHIT are sparse. Hence, present study aimed to find the test-retest reliability of vHIT in individuals with normal auditory and vestibular system across 10 sessions. Twenty participants in the age range of 15-50 years underwent vHIT on 10 separate occasions for each of the 6 semicircular canals using monocular goggles of ICS Impulse vHIT system. Vestobulo-ocular reflex (VOR) gain and head velocity exhibited excellent test-retest reliability across 10 sessions ($\alpha > 0.70$). While asymmetry ratio also demonstrated excellent test-retest reliability in two modules ($\alpha > 0.70$), it was moderate but tending towards excellent in one module ($\alpha > 0.67$). Thus, vHIT is reliable when recordings are repeated over several sessions in healthy individuals.

Key words: vHIT, test-retest reliability, semicircular canals, RALP, LARP, refixation saccades

ACKNOWLEDGEMENTS

First and foremost I would like to extend my gratitude to an excellent teacher and guide as well **Dr.Niraj Kumar Singh,** who was being a great support and source of inspiration throughout. I got to learn many things apart from studies like your sincerity, dedication and punctuality towards work. I make sure I will follow these things throughout my life. And I am also sorry for all the mistakes that I have done in the course of learning, which caused you so much inconvenience sir.

Thanks to **Prof. S.R. Savithri** Director of All India Institute of Speech and Hearing for giving me an opportunity to do dissertation.

Thanks to **Dr.Sandeep .M** HOD Department of Audiology, for being a great teacher and also for permitting me to use the instrument for my dissertation.

Thanks to **all the faculties of AIISH**, who have taught me to make my basics strong. Especially my audiology staffs who were being of interactive and supportive throughout. It is my privilege to study in a great college like AIISH.

I am very thankful to all my participants who came willingly for 'n' number of times, without any hard feelings.

Thanks to **Prashanthprabhu sir**, for clearing all my doubts since BSc, for also guiding me in all the ways.

Thanks to **Ravi sir** for encountering all the problems with my laptop, my data.

Thanks to **Prashanth sir** (software), for helping me to restore my data.

Parents, nothing would have been possible without my **mummy and appa**. Thank you will be a very small word to use with you both. I just want to say "I am very lucky to have born as a daughter" to such an awesome parent.

My ajji, taata, jayaram mama, narasappa mama you all have brought me lot of happiness in my life, I would like to dedicate all my success to you. Whatever i am today it's only because of you all.

Nish my sweetest cutest brother, you were being so irritating, annoying human being on the earth. But no one can take care of me like you bro. I am so fortunate to born with this wonderful soul.

My atte, ruchi, ammu, yashu you all are so wonderful. Thanks for being with me.

Navi, words fall short when I start telling about you. You are my source of motivation and your presence made me smile in all my difficult situations. I am so thankful to you for being in my life and it should last forever.

Chikkatimma uncle you showed me a way to live, when I was left with everything. I am so blessed to have you in my life.

Preethi, you were there with me in all my ups and downs. You were being so understanding, caring throughout these 6 years. Thanks for everything.

Shru I just wish I could have a sister like you. No hard feelings, you are always there for me. I wish you a great life.

Nirmalaakka, you are my guide, teacher, an awesome friend everything. Without you my dissertation would not have been done. Apart from studies, you were being a wonderful human being and I have learnt many many things from you.

I thank **Kirtijoshi and jasiya.** You were being a great dissertation mates by sharing your knowledge and being so supportive all the time.

Rajith you made me to get socialized and you made me more talkative. You added many more joys into my life thank you.

Sangeetha, I have no words to tell you, you mean a lot to me.

Sneha, usha thank you for making my hostel memorable. Prithvi, vasu you guys are awesome. Special thanks to sumanth.

Thanks to everyone who have helped me directly or indirectly.

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CHAPTER I

INTRODUCTION

The human inner ear houses the systems of hearing as well as balance. The structure within the inner ear which helps maintain the body balance is called the vestibular system. The vestibular system provides orientation in three dimensional space, modification of muscle tone and balance (Truex & Carpenter, 1969). This system is also capable of sensing the perturbations in both angular and linear plane. Linear movements are sensed by otolith organs namely utricle and saccule whereas movements in angular plane are sensed by lateral, anterior and posterior semicircular canals. The semicircular canals works in roll, yaw and pitch planes (Angelaki & Cullen, 2008). This is facilitated through the established functional equality between the specific canals which are nowhere connected anatomically. The two lateral canals, right anterior and left posterior canals and right posterior and left anterior canals work together as pairs to maintain the balance in all the three planes.

The functional pairing between the semicircular canals takes place such that excitation (depolarization) in one is reciprocated by inhibition (hyperpolarization) in the other, of a pair. Since the nerve fibers connect to agonist and antagonist pairs of muscles of the eyes, the excitation and inhibition in a pair of the canals causes deviation of the eyes in the respective plane. In case of the lateral canals pair, the head movement to right causes excitation in the right and inhibition in the left semicircular canal. This propels the eye to move in leftward direction with the same velocity and acceleration as the head. In case of the vertical canals, such pairing occurs between anterior and posterior canals and they get activated by head movements in the yaw and pitch planes, thereby propelling the eyes to move in opposite direction to the head in the respective planes. This function is called vestibulo-ocular reflex (VOR) and helps in maintaining

focused vision on an object when the head is moving. When an individual has a deficit in the semicircular canals' functioning or functioning of the fibers originating in them, he/she finds it difficult to maintain focus on an object when the head moves. This can happen in several pathologies affecting the vestibular system like Meniere's disease, BPPV, labyrinthitis, vestibular neuritis, auditory neuropathy spectrum disorder and some brainstem pathologies.

There are several well established clinical tools for the assessment of semicircular canal function. These include bithermal caloric test, supine roll test, Dix-hallpike test and rotatory chair test. While the supine roll test can assess lateral canal and posterior canal functioning is evaluated by Dix-Hallpike test, they can do so only in individuals with BPPV. The bithermal caloric test assesses the responsiveness of the lateral semicircular canal to thermal stimuli but it cannot evaluate the other two canals. Further it is also not an easily tolerated test. The rotatory chair test can evaluate the semicircular canal function, but like caloric, the patient tolerance is a bottle neck with this test. However until 1988, these were the only techniques available for evaluation of semicircular canals. Halmagyi and Curthyos (1988) introduced a new screening tool called the head impulse test (HIT) which is now modified with a video recording facility called the video head impulse test (vHIT).

Need of the study

Several studies have shown promising results of vHIT in diagnosis of vestibular pathologies like Meniere's disease (Nunez, Alvarez, & Fernandez, 2014), vestibular neuritis (Yoo, Kim, Lee, Yang, Lee, & Park, 2016), vestibular schwanoma (Blodow, Blodow, Bloching, Helbig, & Walther, 2015), and BPPV (MacDougall & Gavin, 2013). It was also found to be useful in evaluating clients with dizziness after cochlear implantation (Hain, 2016). However, for a clinician to completely rely on the results, it is imperative that this test produces similar results each time the test is performed. Nonetheless, the studies assessing the test-retest reliability of vHIT are sparse.

Recent studies reported high test-retest reliability of vHIT by virtue of showing no significant difference in VOR gain on ANOVA or Wilcoxon signed rank test between the two sessions (Murane, Mabrey, Pearson, Byrd, & Akin, 2014; Bansal & Sinha, 2016). The statistical procedures used in their studies may not completely explain the range of variability that could be encountered across several sessions and comparison is made only between the two sessions. Therefore, there is a need to study the test-retest reliability of vHIT over several sessions and report the outcome using more appropriate statistical tests.

Aim of the study

The present study aimed to find the test-retest reliability of vHIT in individuals with normal auditory and vestibular system.

Objectives of the study

In order to fulfill the above aim, the following objectives were taken up:

1. To find the test-retest reliability of VOR gain across 10 sessions in healthy individuals.
2. To find the test-retest reliability of refixation saccades across 10 recording sessions in healthy individuals.

CHAPTER II

REVIEW OF LITERATURE

Head impulse test (HIT), which involves use of unpredictable head jerks along the plane of the lateral semicircular canals to notice the presence of refixation saccades to identify the presence of a vestibular pathology, was the precursor to the modern day video head impulse test (vHIT). The inability of the examiner to observe the saccadic movements made during the head movement (covert refixation saccades) due high velocity head impulses frequently resulted in reports of poor sensitivity of HIT for identifying vestibular pathologies (Beynon et al, 1998; Hamid 2005; Harvey et al, 1997). Infact, Hamid (2005) concluded that HIT was positive only when the subject had more than 50% canal paresis. This called for improvisation and use of technology in administering HIT and video recorded version of HIT, vHIT was born.

vHIT as a clinical tool for evaluation of semicircular canals' function was validated against the well regarded gold standard test of semicircular canal function, the sclera search coil (MacDougall et al., 2009). In order to achieve this, the study conducted simultaneous sclera search coil test and horizontal video head impulse test on 8 subjects with normally functioning vestibular system, 6 with vestibular neuritis, 2 individuals with Meniere's disease (1 each with unilateral and bilateral intratympanic gentamicin treatment). Both the tests produced results on average VOR gain, sensitivity and specificity in identifying vestibular pathologies, recording of overt and covert refixation saccades and close concordance with average concordance correlation coefficient of 0.93. Based on these findings, the authors concluded that vHIT as a test for detection of vestibular pathologies is equivalent to sclera search coils. Further they recommended use of vHIT over sclera search coils owing to vHIT being easier to use in a clinical set-up and lack of discomfort in using glasses over contact lenses.

Subsequent to its validation, vHIT has been studied in several peripheral vestibular pathologies and found to be 55% and 40% more sensitive than caloric test for identifying Meniere's disease and vestibular migraine (Blodow et al., 2014). In case of vestibular schawanoma, 82% of the patients showed abnormal vHIT results on the lesioned side (Kim, 2015). These studies therefore high utility of vHIT in identifying peripheral vestibular pathologies and recommended the adoption of vHIT to the clinical battery for evaluating such patients. However, these studies did not investigate the test-retest reliability of this valid test for vestibular evaluation.

Test-retest reliability of vHIT

In order to investigate the test-retest reliability of vHIT, Murane et al (2014) obtained vHIT recordings for all 6 semicircular canals on two occasions on 30 participants in the age range of 18 to 30 years who had normal hearing, a negative history of vestibular or neurological disease, a negative history of cervical spine injury, and normal caloric test results. Repeated measures analysis of variance and subsequent post hoc tests showed no significant difference between the test sessions for any of the 6 semicircular canals. Based on these findings, the authors concluded that vHIT is a reliably repeatable test of semicircular function.

More recently, Bansal and Sinha (2016) studied the test-retest reliability of VOR gain of vHIT on 25 normal young adults who had normal hearing sensitivity and negative history for any vestibular symptoms. vHIT was administered on two separate occasions with an inter-session interval of 15 days for each participant. Friedman's test followed by Wilcoxon signed rank test revealed no significant difference in VOR gain between the test sessions for any of the 6 semicircular canals.

Although the above mentioned studies were well planned with well defined objectives, the statistical procedures used in these studies were no appropriate as these measures compare mean, median or ranks and not the differences between two recordings in the same individual. Usually, test-retest reliability measurements require use of Chronbach's alpha test or inter-class correlation coefficient, both of which were not used in these studies. Further, both the above studies used evaluation spread across only two sessions. Although, it might provide an idea about variability between sessions, a complete range of variability may not be obtained. Assessment of complete range of variability requires multiple recordings, usually 5-10, which was not done in both the above studies. Furthermore, both the above mentioned studies did not report about the test-retest reliability of refixation saccades, which an integral and probably the most important aspect of diagnostic utility of vHIT. Thus, further studies are needed to have better insight into test-retest reliability of vHIT.

CHAPTER III

METHOD

Participants

Twenty participants in the age range of 15-50 years were selected for the study. All of them were students of audiology and speech language pathology. They were selected from a large pool of 500 students randomly. Detailed case history was taken to rule out the history of ear pain and ear discharge, history of medically or surgically treated ear diseases and symptoms associated with audio-vestibular disorders. Otoscopic examination was done to check for any visual abnormalities in the ear canal and the tympanic membrane. Further, all participants had hearing sensitivity within 15 dBHL across frequencies from 250 Hz – 8 kHz. Speech audiometry results were in agreement with pure-tone audiometry (speech reception threshold was within ±5 dBHL of the pure-tone average & speech identification scores were >90%). Subjects also underwent immittance evaluation and all of them had 'A' type tympanogram and presence of acoustic reflexes at 100 dBHL at 500, 1000 and 2000 Hz. All participants had presence of otoacoustic emissions which indicated normal outer hair cell functioning and also normal middle ear functioning.

Fukuda stepping test was carried out by asking the person to stand inside the smaller of the two concentric circles and outstretch hands in front in such a way that they were parallel to the ground and also to each other. He/she was instructed to march with closed eyes at the same place using a total of 50 steps. The results were considered to be abnormal if the angle of the deviation was >45˚ or distance travelled from the starting point was >1 meter (Harit & Singh, 2012). Sharpened Romberg test was done by asking the person to place his/her one foot in front of the other (tandem gait position) and hands were out stretched in a similar way to the Fukuda stepping test. He/she was asked to close his/her eyes and maintain the same posture for 30 seconds. It was considered abnormal if the person did not maintain the same position or started swaying towards any side or had a falling sensation within the stipulated time of 30 seconds. Past pointing test was also administered by instructing the individual to touch the finger tip of the examiner and his/her nose tip alternately while the examiner constantly changed the position of her finger in space. The result of the test was considered abnormal if there were overshoots, undershoots and/or tremors during the task. All participants had normal results on the above mentioned behavioral balance assessment tests. Further, individuals with obvious vestibular problems like Meniere's disease, BPPV, spontaneous nystagmus, labyrinthitis, vestibular neuritis, ANSD, hypertension and diabetes mellitus were excluded from the study. Those fulfilling the above mentioned selection criteria were enrolled to the study upon signing the informed written consent form and they were not paid for their participation in the study.

Instrumentation

The commercially available video head impulse system ICS Impulse was utilized for recording the vestibulo-ocular reflex. The instrument includes hardware as well as software. Hardware consists of mono-ocular goggle with a high speed camera which is capable of recording eye movements at a speed of 250 frames/second. The image of the object is captured after it is reflected from a semi-reflecting glass placed on the goggle. The goggle is mounted with a sensor that senses and provides a measure of the velocity and acceleration of head.

Procedure

A dot indicating the visual target was marked on the wall and the participant was seated on a comfortable chair with his/her head straight at a distance of 1 meter from the target dot. It was ensured that the target dot was at eye level when the participant was seated. The mono-ocular goggle was placed appropriately on the nasal bridge and the strap was altered until tight placement was achieved. This was done to ensure no relative movement between head and the goggle. The region of interest on the pupil was selected prior to the test. Participant was instructed to track the laser light which shifts on either side of the target at equal distance (10 degrees on either side of the target dot on the wall) for the purpose of calibration.

To test the lateral canal, the participant was asked to fixate his/her gaze at the target on the wall. Examiner stood right behind the participant and delivered head impulses of 10˚-20˚ in the lateral canal's (yaw) plane. The introduced head impulses were highly unpredictable to avoid anticipation of direction of the movement by the participant. Instrument provides feedback for the clinician about the speed and degree of deviation of each head impulse. This was used for monitoring the accuracy of speed and plane of movements. Movements which were slow, overshooting or stimulating the wrong plane were rejected automatically. Twenty recordings for each direction of impulse were considered for further analyses.

Functional combination of the vertical canals was assessed by positioning the head at 45˚ towards left or right for alignment of the two vertical canals to come in a sagittal plane. RALP (right anterior left posterior) module was administered by turning the head towards left and LARP (left anterior right posterior) by turning the head towards right. Participant was instructed to fixate gaze on the target on the wall while head impulses were introduced along the sagittal axis (sagittal axis was considered for the head in midline and this midline movement was only used despite the head being turned to left/right). To avoid adaptation or fatigue, a gap of 1-2 minutes was provided between each canal pair. Entire test procedure (lateral, RALP & LARP) was repeated 10 times while ensuring minimum and maximum gaps of 1 day and 1 week respectively between the recordings.

Response analyses

Vestibulo-ocular reflex (VOR) gain was obtained by dividing the eye velocity by head velocity for each head impulse. An average of 20 recordings in each direction was considered the VOR gain for that particular semicircular canal. Refixation saccades were not analyzed objectively since there was a lack of awareness about the usage of HITcalc software. Instead the presence and absence of saccades were analyzed visually. It was considered as present if the saccades were present more than 50% of the time in each canal individually for all 10 trials.

Statistical analyses

The obtained data was subjected to statistical analyses using the commercially available statistically package for social sciences (SPSS) version 17.0. Descriptive statistical analyses were used to obtain mean and standard deviation of the VOR gain for each SCC. Test-retest reliability was evaluated using Chronbach's alpha test and alpha coefficients (α) were noted for each of the three vHIT modules (lateral, RALP and LARP)

CHAPTER IV

RESULTS

The present study was aimed at investigating test-retest reliability of vHIT in healthy individuals across multiple trials. In order to fulfill the specific objectives, each of the 20 participants underwent vHIT recording using lateral, LARP and RALP modules for of the equipment over 10 sessions separated by a minimum and maximum gap of 1 day and 1 week, respectively. Figure 1 shows vHIT recordings from one representative individual across 10 trials for lateral, LARP and RALP modules.

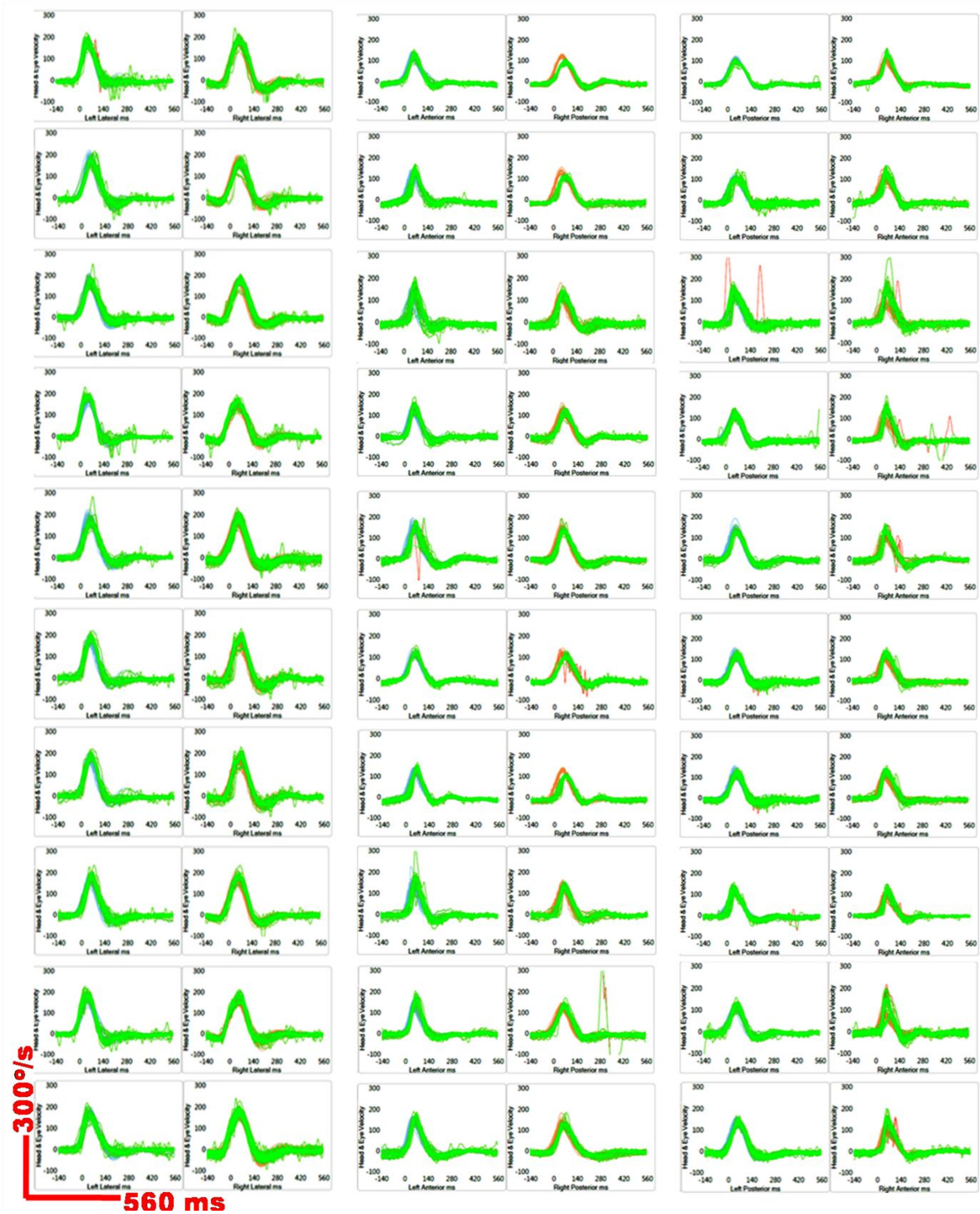

Figure 1: vHIT recordings from a representative participant using lateral (left side first two columns), LARP (middle two columns) and RALP (right side two columns) modules across 10 trials.

VOR gains were calculated and subjected to descriptive statistical analyses for obtaining mean and standard deviation. Table 1 shows mean and standard deviation of VOR gain obtained for all three modules (6 semicircular canals) in all 10 test sessions.

Table 1.

Mean (and standard deviation) of VOR gain for lateral, LARP and LARP modules across 10 trials

Trials	Lateral		LARP		RALP	
	Right	Left	Left anterior	Right posterior	Right anterior	Left posterior
1	1.05 (0.07)	0.98 (0.08)	0.99 (0.08)	0.96 (0.08)	0.99 (0.09)	1.11 (0.10)
2	1.05 (0.09)	0.98 (0.07)	1.03 (0.07)	0.98 (0.06)	1.00 (0.07)	1.09 (0.13)
3	1.05 (0.10)	0.99 (0.08)	0.97 (0.07)	0.95 (0.06)	1.00 (0.11)	1.08 (0.10)
4	1.07 (0.08)	1.01 (0.10)	0.96 (0.07)	0.97 (0.10)	1.00 (0.09)	1.06 (0.08)
5	1.08 (0.11)	1.03 (0.13)	0.96 (0.09)	0.97 (0.08)	1.01 (1.10)	1.09 (0.08)
6	1.05 (0.11)	1.00 (0.14)	0.97 (0.07)	0.98 (0.08)	0.98 (0.10)	1.05 (0.10)
7	1.04 (0.11)	1.01 (0.12)	0.99 (0.08)	0.97 (0.08)	1.01 (0.09)	1.09 (0.08)
8	1.03 (0.08)	0.99 (0.09)	0.96 (0.05)	0.94 (0.06)	1.01 (0.11)	1.07 (0.12)
9	1.04 (0.11)	0.97 (0.06)	0.96 (0.07)	0.96 (0.08)	0.99 (0.07)	1.04 (0.11)
10	1.02 (0.07)	0.97 (0.05)	0.97 (0.05)	0.96 (0.06)	0.98 (0.06)	1.07 (0.10)

Note: 'LARP'- left anterior right posterior; 'RALP'- right anterior left posterior.

Refixaction saccades were operationally defined to be pathological only when at least 50% of the traces for any one side head jerks contained overt or covert saccades. Refixation saccades were not observed in any of the individuals participating in the present study in any of the trials in any module, thereby showing excellent test-retest reliability for its absence.

The data obtained for all 10 trials were subjected to statistical analysis using Cronbach's alpha test as a measure of test-retest reliability of vHIT. The α-values for the VOR gain were 0.90, 0.94, 0.82, 0.78, 0.86 and 0.94 for left lateral, right lateral, and left anterior, right posterior, left posterior and right anterior semicircular canals, respectively. Figure 2 shows mean and 95% confidence intervals of VOR gain in various planes and across trials.

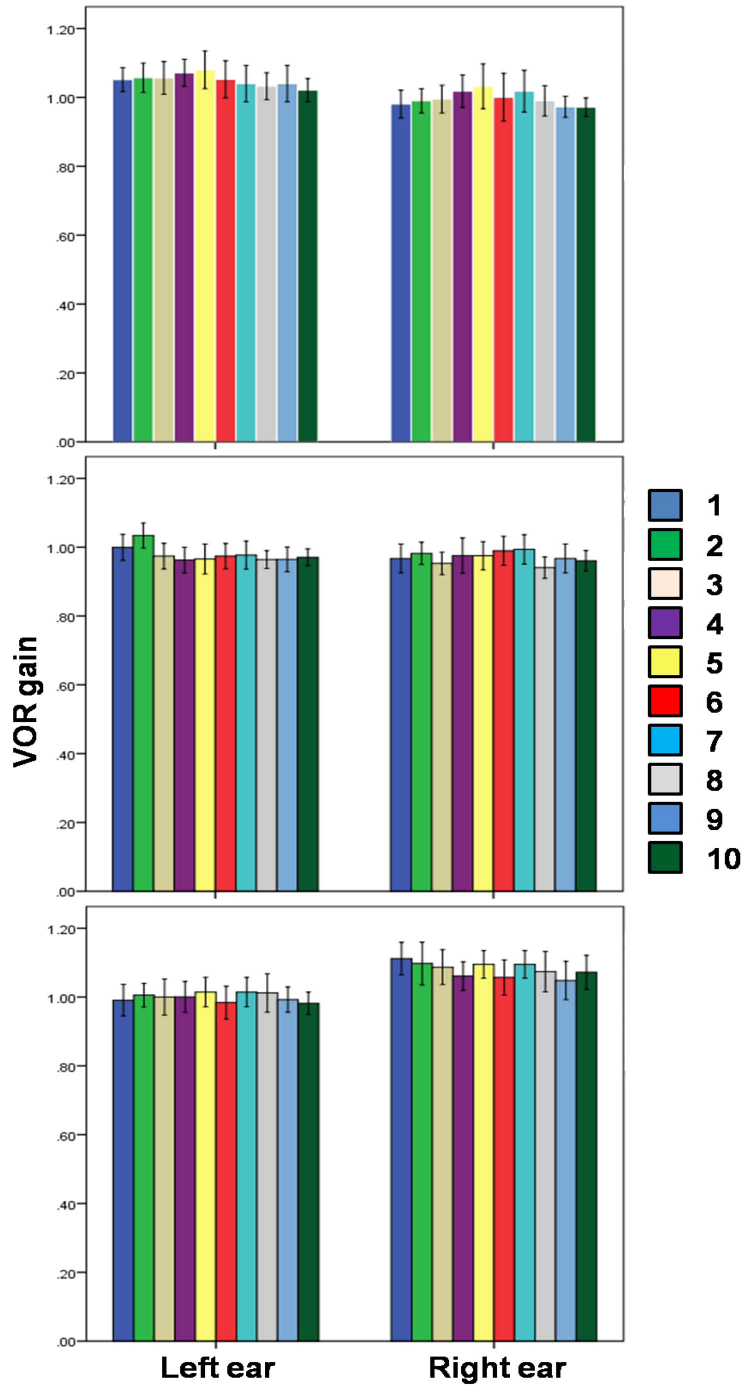

Figure 2: Mean and 95% confidence intervals of VOR gain across 10 trials in both ears forLateral (top panel), anterior (middle panel) and posterior (bottom panel) semicircular canals.

Further, analysis was also done for head velocities in different canals' planes. Mean and standard deviation of head velocities for each side head jerk across 10 trials is shown in Table 2. Chronbach's α-values were measured even for head velocities in all canals for checking the reliability of the head velocity produced by head jerks in respective planes. These were 0.77, 0.74, 0.90, 0.85, 0.85 and 0.77 in right lateral, left lateral, right posterior, left anterior, right anterior and left posterior, respectively.

Table 2.

Mean (and standard deviation) of head velocities across 10 trials

Trials	**Lateral**		**LARP**		**RALP**	
	Right	Left	Left anterior	Right posterior	Right anterior	Left posterior
1	155.55 (20.86)	159.20 (18.32)	115.20 (15.84)	115.75 (18.04)	105.25 (8.83)	108.35 (13.18)
2	150.90 (16.44)	156.00 (17.58)	115.65 (16.04)	113.00 (16.04)	104.70 (10.44)	110.30 (11.04)
3	153.55 (18.19)	156.25 (18.54)	116.10 (10.13)	119.30 (13.47)	105.30 (9.52)	112.85 (12.91)
4	155.15 (14.86)	158.75 (14.29)	123.70 (13.73)	124.40 (15.98)	105.15 (8.41)	116.15 (15.23)
5	155.60 (15.54)	163.30 (18.28)	126.45 (13.32)	127.45 (15.16)	108.20 (9.78)	120.20 (14.20)
6	158.95 (13.83)	164.50 (15.49)	128.00 (13.94)	129.90 (16.16)	111.95 (11.70)	120.70 (12.20)
7	156.95 (15.03)	167.70 (13.53)	129.00 (12.30)	130.05 (16.63)	110.75 (12.62)	122.25 (11.29)
8	157.70 (16.31)	164.15 (13.78)	131.02 (13.08)	130.65 (15.80)	110.00 (10.22)	122.80 (9.69)
9	158.30 (14.29)	156.00 (17.58)	127.10 (13.72)	130.00 (17.51)	110.25 (7.21)	122.05 (11.32)
10	155.75 (12.50)	163.90 (13.97)	129.95 (14.46)	128.50 (14.27)	109.65 (8.15)	126.65 (11.32)

Note: ‘LARP’- left anterior right posterior; ‘RALP’- right anterior left posterior

Asymmetry ratio was obtained for each module by using the Jongkee's formula (Lee, Houlden & Tomlinson, 1999). Mean and standard deviation of asymmetry ratio for all three modules (lateral, LARP & RALP) are shown in Table 3.

Table 3.

Mean and standard deviation of asymmetry ratio for VOR gain across 10 trials

Trials	**Lateral**		**LARP**		**RALP**	
	Mean	SD	Mean	SD	Mean	SD
1	8.10	4.97	7.00	3.62	12.20	4.62
2	6.15	4.72	7.00	4.54	10.75	5.99
3	5.50	5.50	4.40	3.37	12.00	5.13
4	4.85	3.55	4.15	4.49	9.85	5.01
5	6.30	3.94	5.20	4.04	8.35	5.09
6	5.90	3.05	4.85	4.05	10.25	5.10
7	4.40	2.32	3.60	2.39	9.05	4.35
8	4.85	2.92	4.15	4.49	9.70	5.49
9	4.25	2.69	4.10	2.36	9.15	4.92
10	5.00	3.24	3.75	2.24	10.45	4.77

Note: 'SD'- standard deviation.

Asymmetry ratio was evaluated for its test-retest reliability using Chronbach's alpha test. The results showed α-values of 0.84, 0.74 and 0.67 for lateral, LARP and RALP modules, respectively. The mean and 95% confidence intervals of asymmetry ratio are shown in Figure 3.

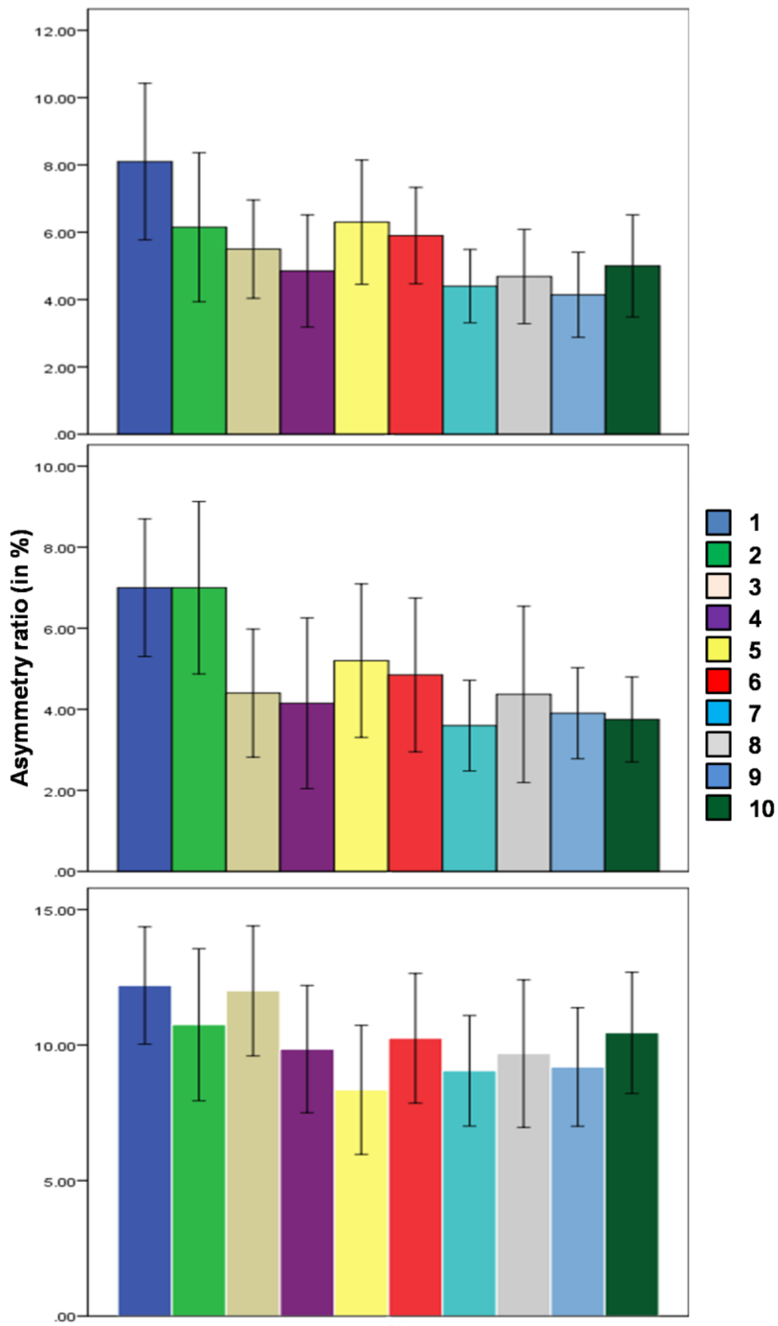

Figure 3: Mean and 95% confidence intervals of asymmetry ratio obtained across 10 trials for lateral (top panel), LARP (middle panel) and RALP (bottom panel) modules of vHIT.

Therefore to summarize the results of the present study, Chronbach α-values were found to be in excess of 0.70 for VOR gain initiated at all the six semicircular canals. Further, asymmetry ratio also produced Chronbach α-values >0.70, except RALP module which demonstrated Chronbach α-value of 0.67.

CHAPTER V

DISCUSSION

Present study aimed to find the test retest reliability of vHIT over several sessions in healthy individuals. For this, each individual underwent vHIT 10 times with minimum and maximum gaps between test sessions being 1 day and 1 week, respectively. A total of 20 healthy individuals participated in the present study. The measures studied were presence of refixation saccades and VOR gain for head impulses in lateral, LARP and RALP planes.

The reliability measure used in the present study was Chronbach's alpha and it revealed α-values >0.76 for VOR gain initiated in each of the 6 semicircular canals. In a study, Versino et al (2001) classified test-retest reliability as excellent, moderate and poor when α-values were >0.7, 0.4-0.7 and <0.4, respectively. Following this classification of test-retest reliability, VOR gain in the present study had excellent test-retest reliability for all 6 semicircular canals. Previous attempts at studying test-retest reliability of VOR gain assessed using vHIT reported high test-retest reliability by observing no significant difference in VOR gain between two test sessions. However, their conclusions were based on findings of repeated measures ANOVA (Murane et al., 2014) or Wilcoxon signed rank test (Bansal & Sinha, 2016). Unfortunately these are measures of central tendencies and therefore compare means, medians or ranks and not the performance of the same individual on two or more occasions. The following example might help in further clarification- a group of six individuals have scores of 1, 2, 3, 4, 5 and 6 in first time testing and the same test when repeated produces scores of 6, 5, 4, 3, 2 and 1. It is evident that test-retest reliability is very poor as subject 1 obtained merely a score of 1 in first trial and a drastically higher score of 6 on second trial. Repeated measures ANOVA or Wilcoxon signed rank test would yield 'no significant difference' which gives a false representation of high test-retest reliability, whereas the fact is that this was an example of really poor test-retest reliability. Thus, the lack of group mean, median or rank difference shown by the above mentioned studies by Murnane et al (2014) and Bansal and Sinha (2016) does not truly represent test-retest reliability of vHIT. The computation of Cronbach's alpha test is an effective tool for measuring the test-retest reliability of any measure (Hatcher, 1994) and hence using this statistical analysis is an appropriate method. Therefore the present study is the first attempt, to the best of our knowledge, at evaluating the test-retest reliability of vHIT in all 6 semicircular canal planes and findings show that VOR gain can be repeatedly obtained with high degree of accuracy and precision.

An important source of variation in VOR gain between two or more test sessions is head velocity. It is believed that VOR gains are appropriately assessed when head velocities are high, usually in the vicinity of 100 degrees/sec or more. Variations in this parameter between the sessions could potentially alter VOR gain. In the present study, head velocity was compared between the sessions in each plane of stimulation and no significant difference in head velocity was observed among the test sessions ($p > 0.05$ on repeated measures analysis of variance). Further, Chronbach's alpha coefficient was > 0.7 for head velocities along all 6 semicircular canals' planes thereby showing excellent test-retest reliability of head velocity. Therefore, maintaining the head velocity in the range used in the present study would yield highly reliable and repeatable vHIT findings.

To the best of our knowledge, previous studies on test-retest reliability of vHIT have not explored the extent to which asymmetry ratio is repeatedly replicated. However, this is an important parameter in evaluation of unilateral vestibular lesions and the findings of the present study show that asymmetry ratio of VOR can be reliably replicated across the test sessions with excellent reliability for 2 of the three modules and moderate (but tending towards excellent with $\alpha = 0.67$) for the other.

The results of present study also showed no refixation saccades in any of the 10 trials for any semicircular canal plane for any of the 20 healthy individuals. This means that absence of refixation saccades, which is measure of peripheral vestibular pathology (MacDougall & Gavin, 2013; Nunez, Alvarez, & Fernandez, 2014; Blodow, Blodow, Bloching, Helbig, & Walther 2015; Hain, 2015; Yoo, Kim, Lee, Yang, Lee, & Park, 2016), is a reliable indicator of normally functioning vestibular system in healthy individuals. However, presence of refixation saccades is a characteristic of uncompensated vestibular dysfunction on one or both sides (MacDougall & Gavin, 2013; Nunez et al., 2014; Blodow et al., 2015; Hain, 2015; Yoo et al., 2016). Therefore complete understanding of test-retest reliability of presence of refixation saccades would be incomplete without studying in the clinical population. This could be studied in future explorations of test-retest reliability of vHIT.

The previous studies have considered only 2 sessions for assessing the reliability of VOR gain which might not be appropriate to explain the extent of variability, especially when the test is used on several occasions in case of using this as a measure of treatment outcomes. If only 2 sessions yield a good reliability it could possibly also be because of the chance factor. Hence considering many trials will give a clear idea about the variability of VOR gain. The findings of the present study therefore throw light on the extent of variability and confirm that the variability of VOR gain is considerably low for vHIT.

CHAPTER VI

SUMMARY AND CONCLUSION

Video head impulse test is a new addition to the test battery meant for evaluation of vestibular system's functioning. Recent literature is suggestive of its utility in the diagnosis of several vestibulopathies like Meniere's disease, vestibular neuritis/labyrinthitis, and several other pathologies. However, a test cannot be relied upon unless its repeated measurements show same results. Two previous studies in this regard (Murnane et al., 2014; Sinha & Bansal, 2016) concluded that vHIT had a high degree of test-retest reliability based on the results of statistical procedures that compare the central tendencies and ranks within a group. Unfortunately, the most effective measure of test-retest reliability, Chrobach alpha test, was not used in both these studies, thereby rendering their conclusions erroneous. Further, they also compared only two recordings which do not quite sufficiently reflect upon the true range of variability in the results of vHIT. Therefore, the present study was done with aim of evaluating test-retest reliability of vHIT over a number of sessions and using appropriate statistical procedures.

A total of 20 healthy individuals with no known history of auditory and vestibular disorders underwent vHIT using lateral, RALP and LARP modules of the ICS impulse video head impulse test. Each individual was tested over 10 sessions with minimum and maximum gap between test sessions being 1 day and 1 week, respectively. The parameters documented were average VOR gain for each canal in each session, asymmetry ratio of VOR gain and presence/absence of refixation saccades.

Reliability was measured using Chronbach's alpha test for VOR gain, head velocity and asymmetry ratio. The reliability of VOR gain as well as the head velocity was found to be excellent for all the six semicircular canals ($\alpha > 0.70$). Test-retest reliability of asymmetry ratio was found be excellent in two modules (lateral & LARP) and tending towards excellent in one module (RALP; $\alpha = 0.67$). This shows reliably replicable head velocities produce reliably repeatable VOR gain. Further, there was no refixation saccade in any module in any trial in any individual. This shows excellent reliability of this measure also, at least among healthy individuals.

Clinical applications of the study outcomes

With its promising test-retest reliability, vHIT can be used as diagnostic tool in the test battery of audio-vestibular evaluation. Further, although not investigated in the present study, high degree of test-retest reliability obtained over a sufficiently large number of trials shows that the results do not vary without intervention. Therefore, future beholds its utility as an outcome measure for treatment efficacy.

Limitations and future directions

The present study has some limitations in implications because of inclusion of only 20 participants. Use of large sample size might have yielded a more robust understanding of the test-retest reliability. Further, the study did not include clinical population, the inclusion of which might have thrown more light on the test-retest reliability of refixation saccades, an important measure in evaluation of vestibulopathies when using vHIT. These can be included in the future studies; however, keeping ethics in view, keeping an individual untreated for any length of time might come in the way of such a study in the clinical population.

REFERENCES

Angelaki, D. E., & Cullen, K. E. (2008). Vestibular system: the many facets of a multimodal sense. Annu. Rev. Neurosci., 31, 125-150.

Bansal, S., & Sinha, S. K. (2016). Assessment of VOR gain function and its test–retest reliability in normal hearing individuals. European Archives of Oto-Rhino-Laryngology, 1-7 DOI: 10.1007/s00405-016-3951-3.

Beynon, G. J., Jani, P., &Baguley, D. M. (1998). A clinical evaluation of head impulse testing.Clinical otolaryngology and allied sciences, 23(2), 117-122.

Blodow, A., Blodow, J., Bloching, M. B., Helbig, R., & Walther, L. E. (2015). Horizontal VOR function shows frequency dynamics in vestibular schwannoma. European Archives of Oto-Rhino-Laryngology, 272(9), 2143-2148.

Chen, L., Todd, M., Halmagyi, G. M., & Aw, S. (2014). Head impulse gain and saccade analysis in pontine-cerebellar stroke and vestibular neuritis. Neurology, 83(17), 1513-1522.

Eza-Nunez, P., Farinas-Alvarez, C., & Perez-Fernandez, N. (2014).The Caloric Test and the Video Head-Impulse Test in Patients with Vertigo.The Journal of International Advanced Otology 10(2), 144-9.

Hain, T. C., & Life, L. A. M. (1997).Vestibular Neuritis and Labyrinthitis.Northwestern University Medical School.

Halmagyi, G. M., & Curthoys, I. S. (1988). A clinical sign of canal paresis. Archives of Neurology, 45(7), 737-739

Hamid, M. (2005). More than a 50% canal paresis is needed for the head impulse test to be positive. Otology &neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology, 26(2), 318.

Harvey, S. A., Wood, D. J., & Feroah, T. R. (1997). Relationship of the head impulse test and head-shake nystagmus in reference to caloric testing. Otology &Neurotology, 18(2), 207-213.

Hatcher, L. (1994).Developing measurement models with confirmatory factor analysis. A step-by-step approach to using the SAS® System for factor Analysis and Structural Equation Modeling (ed.), 249-342.

Henry, D. F. (1999).Test-retest reliability of open-loop bithermal caloric irrigation responses from healthy young adults. Otology & Neurotology, 20(2), 220-222.

Harit, S. K., Singh, G., & Tyagi, N. (2012, November).Fox-hole model for data-centric misbehaviour detection in vanets. In Computer and Communication Technology (ICCCT), 2012 Third International Conference on (pp. 271-277). IEEE.

Kim, H. J., Park, S. H., Kim, J. S., Koo, J. W., Kim, C. Y., Kim, Y. H., & Han, J. H. (2016). Bilaterally abnormal head impulse tests indicate a large cerebellopontine angle tumor. Journal of Clinical Neurology, 12(1), 65-74.

MacDougall, H. G., Weber, K. P., McGarvie, L. A., Halmagyi, G. M., &Curthoys, I. S. (2009). The video head impulse test Diagnostic accuracy in peripheral vestibulopathy. Neurology, 73(14), 1134-1141.

MacDougall, H. G., McGarvie, L. A., Halmagyi, G. M., Curthoys, I. S., & Weber, K. P. (2013). The video head impulse test (vHIT) detects vertical semicircular canal dysfunction. PLoS One, 8(4), e61488.

Murnane, O., Mabrey, H., Pearson, A., Byrd, S., & Akin, F. (2014).Normative data and test-retest reliability of the SYNAPSYS video head impulse test. Journal of the American Academy of Audiology, 25(3), 244-252.

Tascioglu, A. B. (2005). Brief review of vestibular system anatomy and its higher order projections.Neuroanatomy, 4, 24-27.

Wuyts, F. (2008). Principle of the head impulse (thrust) test or Halmagyi head thrust test (HHTT). Royal Belgian Society for ENT and Head and Neck Surgery, 3, 23-26.

Yoo, M. H., Kim, S. H., Lee, J. Y., Yang, C. J., Lee, H. S., & Park, H. J. (2016). Results of video head impulse and caloric tests in 36 patients with vestibular migraine and 23 patients with vestibular neuritis: a preliminary report. Clinical Otolaryngology.doi: 10.1111/coa.12556.