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Original Research Article

Does vestibulo-ocular reflex gain measured by video head impulse test decrease with age?

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ABSTRACT

Backgrounds: The Video Head Impulse Test (vHIT) is used to test the function of each of the six semicircular canals. Each semicircular canal is tested by measuring eye rotation in response to head movements in the plane of the canal and is calculated as the Vestibulo-ocular reflex (VOR) gain. The aims of the study were firstly, to determine age-dependent normative values of VOR gain for the vHIT of semicircular canal function in healthy Asian subjects in each decade year of life. Secondly, to investigate if vHIT measured VOR gain decreases with age.
Methods: A prospective cohort study of 60 healthy voluntary community-dwelling subjects, between 21 to 80 years of age. Subjects with prior history of vertigo were excluded. vHIT was conducted on each subject and analysed with the Interacoustics (EyeSeeCam) video goggles by the senior audiologist. The VOR gain for all six semicircular canals were calculated for each subject.
Results: The mean (SD) vHIT (VOR) gain of all the 6 semicircular canals for the entire population were 1.18 (0.19). The mean of the VOR gain for each of the six semicircular canals were analysed to develop a normative guide. The mean VOR gain per decade year did not vary significantly with age (p=0.417). The correlation between age and mean VOR values was negligible (pearson's r=0.121).
Conclusions: We propose that our normative age-dependent data guide be used to improve the differentiation between normal and abnormal values of VOR gain in an Asian population. Our study shows that VOR gain is not associated with aging.

Keywords: Video head impulse test, Vestibulo-ocular reflex gain, Aging, Normative data

INTRODUCTION

The prevalence of dizziness in general practice varies between 1.0 % to 15.5%, of which the most common etiology is vestibular/peripheral (5.4-42.1%) based on a recent systematic review.[1] The semicircular canals are the key organs which help to control and maintain balance. The Video Head Impulse Test (vHIT) system is designed to detect semicircular canal dysfunction which can often go undiagnosed during clinical examination of patients with dizziness. The development of objective measurements of the vestibulo-ocular reflex (VOR) in response to natural values of head angular acceleration – the vHIT – has been invaluable in identifying horizontal semicircular canal loss, either unilateral or bilateral.[2] Recently, vHIT has been extended to testing vertical canal function, allowing fast, simple and accurate assessment of the functional status of each of the six semicircular canals individually.[3,4] vHIT has been validated by direct simultaneous comparison of vHIT with scleral search coils on the same eye of healthy subjects and patients with known vestibular loss, including those after unilateral vestibular schwannoma operations.[2,4] The usual measure of performance has been the gain of the VOR, and some values of normal VOR gain, averaged across healthy subjects, have been published.[3,4] More recently, studies have also determined the normative values for VOR gain in healthy subject in each decade of life.[5-7] However, these values have limitations: they are based on a relatively small number of subjects and they are not based on an Asian population. The present study aims to overcome some of these limitations.

Several normative studies based on video-analysis of eye responses to head impulses exist. Studies need to account for the well-known factors that influence VOR gain and time constant: target proximity, mental set, active or passive performance, subject age, and velocity of the stimulus.[5-8] In this study, we would like to address the issue of whether (VOR) gain decreases with age in all 3 semi-circular canals.

Our objectives were to determine age-dependent normative values of VOR gain for the vHIT of semicircular canal function in healthy Asian subjects in each decade year of life, and more importantly to examine whether VOR gain measured by vHIT decreases with age.

METHODS

We conducted a prospective cohort study of 60 healthy voluntary community-dwelling subjects, between 21 to 80 years of age. Subjects with prior history of vertigo were excluded. Subjects were recruited through flyers placed on prominent locations in the hospital and were reimbursed S$50 each for their participation in the study. All subjects provided written informed consent. The study protocol was approved by the National Health Group Domain Specific Review Board (DSRB). This study was funded by the Alexandra Health Enabling grant (AHEG1625). Subjects were recruited between March 2016 to March 2017. A sample size of 60 was chosen based on previous studies in the literature and also limited by the grant funding.

Video head impulse tests were carried out with the Interacoustics (EyeSeeCam) video goggles. (Figure 1) The subjects were tested in a well-lit room (to ensure small pupil size) with an eye level target of minimum distance of 1m in front of them. The goggles were fitted firmly on the nose bridge and calibrated. The test was performed by one senior audiologist with prior experience with vHIT to ensure consistency in the results. To test the horizontal semicircular canals, the subject was instructed to maintain visual fixation on a target fixed straight ahead with the head pitched downwards approximately 20 degrees. The operator then delivered brief, passive head turns. To test the vertical canals, the head impulses were delivered in the plane of the canal paired under test. The vertical canals are oriented in planes about 45° to the median plane of the head and form two canal pairs – left anterior–right posterior (LARP) and right anterior–left posterior (RALP). To test the LARP canals, the subject was instructed to visually fixate the central fixation point eccentrically. Thus, a diagonal head pitch forward (toward the fixation target) activates the left anterior canal and causes an upward eye movement, and a head pitch back (away from the fixation target) activates the right posterior canal and causes a downward eye movement.

The VOR gain was measured for all six semicircular canals for subjects in decade age bands. Subjects with covert and overt saccades on the vHIT were excluded.

Statistical analysis was performed using Stata (version 13.1, College Station, TX: StataCorp LP), significance tests were 2-sided at the 5% significance level. Data normality was checked using Shapiro-Wilk normality test.

The difference in mean VOR gain, overall and by lateral, anterior and posterior canal between age groups (21-30 versus 31-40 versus 41-50 versus 51-60 versus 61-80 years) was assessed using ANOVA (Analysis of Variance). Further analysis was done to examine p-value for trend using linear regression models to assess if there was a trend in mean VOR gain across the age decades. Paired t-test was used to assess whether right versus left mean VOR gains were different by lateral, anterior and posterior canal. Pearson correlation was used to examine the direction and strength of correlation between age (taken as linear continuous variable) and mean VOR gain. Results are reported as count (n) and percentage for categorical data and mean, standard deviation (SD) for continuous data. Statistics were performed by a statistician.

RESULTS

Sixty subjects were recruited, but only 53 subjects were included in final analysis after excluding 7 subjects.

Table 1: VOR gain by age group.

	Total	21-30	31-40	41-50	51-60	61-80	P value (ANOVA)
Number (%)	53	13 (24.53)	10 (18.87)	8 (15.09)	10 (18.87)	12 (22.64)	-
Age years, mean (SD)	45.4 (15.5)	26.5 (2.5)	34.9 (3.1)	44.6 (3.5)	55.6 (2.4)	66.5 (3.3)	<0.001
Mean VOR gain, mean (SD)	1.183 (0.190)	1.154 (0.202)	1.121 (0.207)	1.28 (0.164)	1.170 (0.224)	1.209 (0.144)	0.417

Continued.

	Total	21-30	31-40	41-50	51-60	61-80	P value (ANOVA)
Mean VOR gain-lateral, mean (SD)	1.260 (0.288)	1.273 (0.201)	1.187 (0.299)	1.310 (0.259)	1.173 (0.437)	1.347 (0.232)	0.585
Mean VOR gain right lateral, mean (SD)	1.209 (0.323)	1.257 (0.267)	1.093 (0.267)	1.24 (0.293)	1.143 (0.504)	1.288 (0.259)	0.610
Mean VOR gain left lateral, mean (SD)	1.311 (0.296)	1.288 (0.208)	1.28 (0.369)	1.381 (0.263)	1.203 (0.381)	1.407 (0.261)	0.537
Mean VOR gain right anterior, mean (SD)	1.385 (0.357)	1.298 (0.379)	1.275 (0.298)	1.588 (0.292)	1.38 (0.394)	1.44 (0.371)	0.339
Mean VOR gain left anterior, mean (SD)	0.990 (0.202)	0.992 (0.239)	0.965 (0.140)	1.015 (0.207)	1.005 (0.189)	0.981 (0.238)	0.987
Mean VOR gain right posterior, mean (SD)	0.879 (0.169)	0.890 (0.184)	0.823 (0.165)	0.91 (0.215)	0.908 (0.132)	0.871 (0.169)	0.796
Mean VOR gain left posterior, mean (SD)	1.323 (0.352)	1.196 (0.341)	1.288 (0.351)	1.584 (0.254)	1.382 (0.407)	1.266 (0.322)	0.143

Of the 7 subjects that were excluded, 1 withdrew due to the detection of vestibular hypofunction, 2 had overt saccades and 4 had hyper-gain. The mean age of the cohort was 45.4 years. The mean (SD) VOR gain for the cohort was 1.18 (0.19). The mean of the VOR gain for each of the six semicircular canals were analysed to develop a normative guide.

Table 2: Comparison of right versus left VOR gain.

	Mean VOR gain, mean (SD)	P value (paired t-test)
Right lateral	1.209 (0.323)	0.002
Left lateral	1.311 (0.296)	
Right anterior	1.385 (0.357)	<0.001
Left anterior	0.990 (0.202)	
Right posterior	0.879 (0.169)	<0.001
Left posterior	1.323 (0.352)	

Table 3: Correlation between age and mean VOR.

	Pearson's correlation coefficient (r)	P-value for correlation
Mean VOR gain	0.121	0.389
Mean VOR gain right lateral	0.035	0.803
Mean VOR gain left lateral	0.066	0.637
Mean VOR gain right anterior	0.180	0.196
Mean VOR gain left anterior	0.001	0.996
Mean VOR gain right posterior	0.029	0.838
Mean VOR gain left posterior	0.106	0.447

Figure 1: Interacoustics (EyeSeeCam) video goggles.

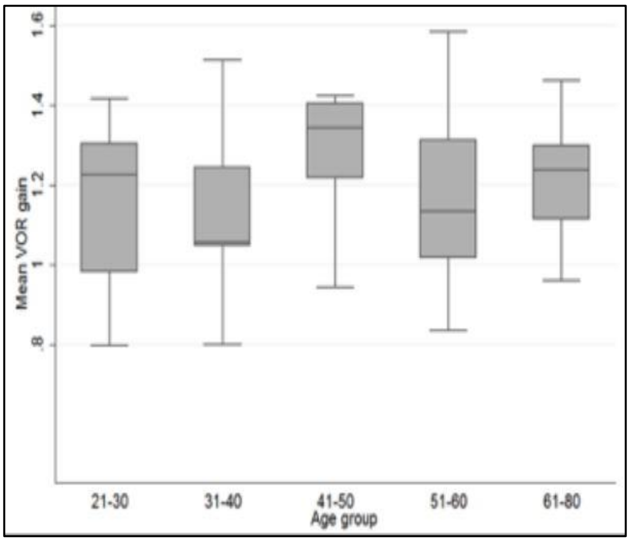

Figure 2: Mean VOR Gain over all 6 semicircular canals.

The mean VOR gain of each decade year was compared to the decade prior. The decades 60-70 years of age and 70-80 years of age were combined for analysis as the latter had only 2 subjects (Table 1). ANOVA showed that the mean VOR gain per decade year did not vary significantly with age. (Figure 2) The ANOVA for the mean VOR gain for the individual canals per decade year also did not vary significantly with age (Figure 3). Interestingly, the paired t-tests in the mean VOR gain showed a significance between the right and left lateral, anterior and posteriorly semicircular canals (Table 2). This is postulated to be due to our audiologist being right handed leading to the difference in values. Pearsons correlation showed that the correlation between age and mean VOR values was negligible and age is unlikely to influence mean VOR gain (Table 3).

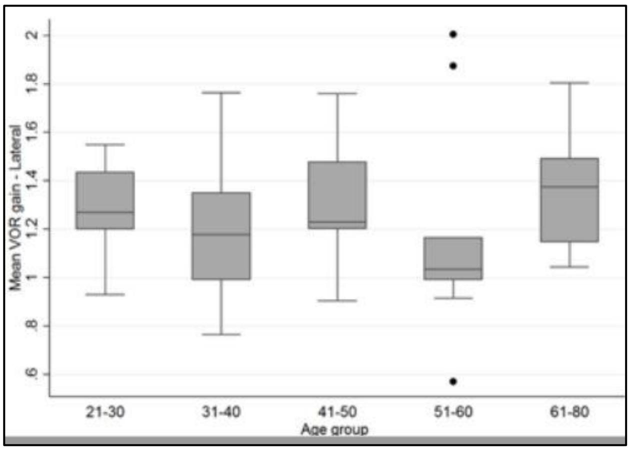

Figure 3: Mean VOR gain for the lateral canals.

DISCUSSION

The effect of age on VOR gain has been a topic of interest over the last several years. Matin˜o-Soler et al. studied the effect of age, head velocity, sex, and direction of stimulus on horizontal VOR gain using vHIT on 212 healthy subjects. The horizontal VOR gain was stable until age of 71 years, where the gain was significantly reduced at a higher velocity vHIT. With increasing age between 71 and 91 years, the VOR gain reduction was found at lower velocity vHIT. At 91 years and above, the gain was significantly reduced for any horizontal vHIT velocity.[8] This can be explained by loss of hair cells and vestibular nerve fibers that occur with increasing age, which can be named as presbyvestibulis.[9] Yang et al. similarly studied 50 healthy subjects and found that the vHIT gains were near 1.0 (1.02 ± 0.07) in normal subjects in their 20's to 60's.5 Our study of 53 subjects age between 21 to 80 years old, concurs with the Yang et al. study as the mean VOR gain for all canals per decade year did not vary significantly with age. Evidence shows that there is a loss of vestibular receptor cells and primary afferents with age.[10-12] Perhaps the reason our study did not illustrate reduction of VOR gain was due to the fact that our subjects were skewed towards the younger population. Alternatively, given the VHIT targets the ampulla of the semi-circular canals, it may not necessarily detect the loss of vestibular function that occurs in the vestibular nerve fibres.

The crista ampullaris is the receptor for angular VOR, and it consists of type I and type II hair cells. Type I is located at the center of crista ampullaris and type II is located at the periphery. Type I hair cells are mainly connected to the irregular afferents that encode for the high-frequency, high acceleration head movement. Type II cells are mainly connected to the regular cells that encode for low-frequency, low-acceleration head movement.[13] The velocity of the head movement determines which system will take over to stabilize the image on the retina. At low-frequency head movement (0.001 Hz), vision predominates. At high-frequency head movement (5 Hz), retinal image stability is under vestibular control. The eye movements are driven by the difference between the excitatory and inhibitory responses which is proportional to the head movement and that means the eye velocity is equal the head velocity in the opposite direction. Clinical Head Impulse Test (cHIT) is an objective test that depends on the clinician's visual observation.[7] The overt saccades could be masked by covert saccades thus increasing the false negative result. To overcome this difficulty, the vHIT is able to show overt, covert saccades, and gain deficit. vHIT measures directly the VOR gain by calculating the velocity ratio between the head impulse and gaze deviation.[14]

With regard to directional differences, our study showed that there was a significant difference for the right VOR gain for all 3 semi-circular canals compared to their matched left semi-circular canals. These findings were similar to McGarvie et al. study in 2015 where this was attributed to only the right eye being measured which was similar to our study.[15] As the head rotates to the right, the right eye has to make a slightly larger rotation within the skull to remain fixated on a target 1 m from the subject, in comparison to the left eye. The effect is reversed for an impulse rotation to the left. This effect has also been confirmed by measuring both eyes with dual search coils, which has shown up to 15% difference in the slope gain between the adducting and abducting eyes at high velocities during head impulses.[15]

Our study aimed to develop normative values for an Asian population by ensuring our subjects had no prior history of vertigo. These subjects were independent, healthy and from the community. Also, we ensured standardization by having the vHIT performed by our one senior audiologist with many years of experience performing the vHIT. We also analysed data in not only the lateral canal but in all 3 semi-circular canals. There were several limitations to our study. Firstly, our numbers were limited mainly by our funding availability. Secondly, it was challenging to recruit subjects who were above 60 with no prior history of vertigo as many of them inevitably would have a previous experience of imbalance or have general medical conditions potentially limiting their involvement.

CONCLUSION

We propose that our normative age-dependent data guide be used to improve the differentiation between normal and abnormal values of VOR gain in an Asian population. This will help guide us for determining patients with vestibular hypofunction, especially those with bilateral vestibular hypofunction. Our study shows that VOR gain, as measured directly by the eye movement response to head rotation, seems largely unaffected by aging. Therefore allowing the normative values to be extended throughout the age groups.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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