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RESEARCH ARTICLE

Normative vestibulo-ocular reflex data in 6-12 year-old children using video head-impulse test

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Abstract

Background and Aim: The video head-impulse test (vHIT) is a useful clinical tool to measure vestibulo-ocular reflex (VOR) gain that is defined as the ratio of eye velocity to head velocity. Although normative data are available for VOR gain, most studies only report horizontal semicircular canal VOR in adults and overlooked children. Hence, this study aimed at establishing normative VOR data for 6-12 years old children.

Methods: Vestibulo-ocular reflex gain in horizontal and vertical planes was assessed on 60 healthy children without a history of balance and hearing problems using sudden, fast, and unpredictable head impulses.

Results: The mean and standard deviation of VOR gains were 0.99 (0.05), 0.98 (0.06), and 0.93 (0.06) for horizontal, anterior, and posterior canals, respectively. Gain differences between genders were not statistically significant.

Conclusion: The simplicity and tolerability of vHIT in children showed that it can be used as a screening tool to diagnose vestibular disorders in children. In addition, it was seen that mean VOR gain is greater in horizontal canal than vertical canal.

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Introduction

Based on the studies and available evidence, the incidence of vestibular disorders in children is considerably increasing that may result in dysfunction in motor development, such as motor and postural control in childhood [1]. The balance system evaluation is one of the most important measures for child development evaluation. Vestibular disorder may cause a delay in the acquisition of postural control, periodic vertigo, and paroxysmal head tilt in younger children that cannot be detected up to adulthood [2]. There are two roles for postural control that include maintaining body position against gravity to reach balance and stabilizing the correct orientation of organs used as sources for perception of the environment [3]. If postural disorders are not diagnosed early, they may cause a deficiency in motor skills such as gait disorder and balance dysfunction in childhood and adolescence. These disorders can cause severe difficulties in motor function [4]. Assessment of children's vestibular system can provide important information on the diagnosis and presentation of appropriate rehabilitation strategies for children with balance, vestibular (either accompanied by hearing impairment or not) as well as other developmental disorders [5].

Accurate diagnosis of vestibular dysfunction in children, compared to adults, bears many challenges. The child is unable to explain the symptoms, such as dizziness, imbalance, torticollis, and motor latency [6]. Therefore, this shows the importance of vestibular test in children although performing these tests on children is very difficult. One of the difficulties in the evaluation of balance in children is the lack of standardized tests and protocols for diagnosis in this age group [7].

Vestibulo-ocular reflex (VOR) causes involuntary movements of the eyes in the opposite direction of the head movement that make images fixed on the retina during head movement. Measurement of VOR is the most accessible scale for evaluating the function of the vestibular system and forms one of the most important parts of the evaluation system in human beings. Evaluating VOR requires applying vestibular stimulus and measuring subsequent eye movement [6].

There are several methods for the evaluation of VOR function. One of the latest methods is video head-impulse test (vHIT), which was introduced by Curthoys and Halmagyi in 1988. Through this test, it is possible to assess VOR gain fast and accurately in high frequencies of head movement [8]. In this test, the patient gazes at a target in his or her front while the examiner moves the patient's head fast, suddenly, and unpredictably in horizontal and vertical directions, and eye movement is tested for detecting catch-up saccade [9]. In case of normal VOR, as head moves, the eyes move in opposition to the head movement, causing the image to be fixed on the retina. However, in case of an impairment in semicircular canals (SCCs), insufficient VOR and considerable catch-up saccade will be observed when head impulses are in the direction of canal [10].

Unlike most vestibular tests such as caloric test and rotatory chair that examine vestibular system in low frequencies, vHIT evaluates VOR gain and SCCs function through high-frequency physiological stimuli covering optimized functional range of the vestibular receptors and routine head movements. Moreover, in comparison to other tests (such as caloric test and rotatory chair), vHIT is capable of evaluating each SCC, separately. Another advantage of vHIT to caloric test is that in abnormalities of the vestibular nerve, such as vestibular neuritis, it can help detect which branch of the vestibular nerve or its afferent is involved [11,12].

An important feature of this test is its effectiveness on children. Since classic tests such as caloric test and rotatory chair are difficult to stand by children (due to stress, fear, dizziness, and vertigo), vHIT has drawn more attention. This test is done in a bright room with sufficient light, and unlike other tests, it makes no fear and vertigo and is tolerable for this age group. Thus, it can easily be done on children [7,8].

One of the reasons that vHIT could not be used as a clinical balance function test in children is the lack of age-matched normal data for them. Therefore, this study aimed to present normal data in children in the age range of 6-12 years. For this, the vHIT was used as a complementary diagnostic tool to evaluate and manage balance disorders in children more accurately.

Methods

We selected 60 normal hearing children aged 6 to 12 years (35 boys) with no history of balance and vision disorders from Tehran schools. To ensure the normal function of hearing, pure tone audiometry (in 250-8000 Hz) and acoustic immittance (tympanometry in low frequency and acoustic reflex) were conducted. After obtaining parental written consent, the participants were instructed about their task during the test.

To record eye and head movements in response to sudden, low amplitude, unpredictable and high acceleration head impulses, vHIT Ulmer (Synapsys, France) was used. This system comprised a high-speed infrared digital camera (100 Hz) and a laptop with vHIT software. The camera was on a tripod adjustable in height by software manually.

The test was conducted as follows: the participants were asked to sit on a chair 1 m from the camera gazing at the moving target displayed by vHIT software on a screen placed 2 m in front of them. They were also asked to keep the eyes open and not to blink. The camera was placed

Table 1. Mean (standard deviation), minimum and maximum vestibulo-ocular reflex gain in left and right semicircular canals in normal children

	VOR gain in the right side			VOR gain in the left side				Total VOR gain
Canal	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**p**	**Mean (SD)**
Horizontal	0.99 (0.05)	0.87	1.14	1.00 (0.04)	0.90	1.12	0.89	0.99 (0.05)
Anterior	0.98 (0.06)	0.85	1.10	0.98 (0.06)	0.78	1.11	0.57	0.98 (0.06)
Posterior	0.94 (0.06)	0.83	1.10	0.94 (0.05)	0.78	1.14	0.41	0.94 (0.06)

VOR: vestibule-ocular reflex

between the participant and the moving target, and the visual target was able to automatically detect the cornea and to record responses using vHIT Ulmer.

The vHIT Ulmer software could accurately detect the direction of the head movement, in other words the stimulatory channel, and announce it by voice while determining the movement direction with three color boxes. For example, if the head is rotated 35 degrees to the right, the blue color box that indicates the left anterior right posterior (LARP) will get on. For stimulating the horizontal SCCs, the patient's head suddenly moves to the right and left unpredictably with high acceleration (2500 deg/s^2) and low amplitude (10-30 degrees).

To perform vHIT in the right anterior left posterior (RALP) plane, the participant head was turned 35-45 degrees to the left and then, movements with high acceleration and low amplitude presented up and down. In testing the LARP, the head moved 35-45 degrees to the right, and then, movements with high acceleration and low amplitude presented up and down. The mean gain in all planes was collected by the system.

In order to acquire responses, at least five impulses in each direction for SCCs stimulation were used. After each impulse, the head was returned to original position and after a brief (1-2 s) rest, the next impulse was presented unpredictably. The minimum required acceleration was considered to be 2500 deg/s^2 for recording horizontal SCCs and 1500 deg/s^2 for vertical SCCs. The VOR gain was calculated after testing. All impulses were presented by a right-handed examiner.

All statistical analyses were performed using SPSS21 (IBM Corp., US). Kolmogorov-Smirnov test was applied to check the normal distribution of data. Since the data were normally distributed, the parametric statistical methods were utilized. To compare VOR gain in each SCC between genders, Independent t-test was done, and to compare the gain between two ears, the paired t-test was used.

Results

The present study was conducted on 60 children with normal balance and hearing in the age range of 6-12 years with a mean (SD) age of 9 (0.5) years.

The VOR gain obtained in the right and left ears in all three SCCs was analyzed. Although there was a difference between the right and left SCCs VOR gain, the difference was not statistically significant (p>0.05). The VOR gain values are shown in Table 1.

Since the purpose of this study was to obtain normal data for each SCC, the mean value of VOR gain was calculated by summing the values for right and left ears. The mean (SD) VOR gain of horizontal, anterior, and posterior SCCs were 0.99 (0.05), 0.98 (0.06), and 0.94 (0.06), respectively. The mean gain of posterior SCCs was less than that of horizontal and anterior SCCs.

The VOR gain of SCCs was not affected by gender (p>0.05). Table 2 presents the mean VOR gain for each SCC in two different genders.

Table 2. Comparison of mean (standard deviation) vestibulo-ocular reflex gain between genders

	VOR gain in boys			VOR gain in girls			
Canal	**Mean(SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**p**
Horizontal	1.00 (0.05)	0.87	1.14	0.99 (0.06)	0.92	1.12	0.53
Anterior	0.99 (0.07)	0.83	1.08	0.97 (0.06)	0.78	1.11	0.72
Posterior	0.95 (0.05)	0.82	1.14	0.93 (0.06)	0.78	1.09	0.16

VOR: vestibule-ocular reflex

Discussion

In this study, the VOR gain in horizontal and vertical SCCs was studied in 6-12 years old children with normal hearing and balance by vHIT. The main aim of this study was to obtain normal data for VOR in this age. We reported the VOR gain of each SCC separately, and the effects of ear (right and left) and gender were also examined.

In this study, the VOR gain of horizontal, anterior, and posterior SCCs was obtained as 0.99, 0.98, and 0.94, respectively. These findings were consistent with previous studies, which [8,10,13-16] reported the VOR gain in the range of 0.80 to 1.20. Moreover, Hülse et al. [17] obtained the mean gain of 1.02 for horizontal SCCs in 36 children in the age range of 3-16 years while Nassif et al. [18] reported the value of 0.90 in 20 normal children (5-17 years old).

Hamilton et al. [7] measured VOR gain in 20 participants in three age groups of 3-10, 11-14, and 15-19 years and obtained the VOR mean gain values of 0.84, 0.97, and 0.96, respectively. Pepaś et al. [19] and Khater and Afifi [20] obtained the VOR gain of normal children in horizontal and vertical SCCs as 0.90 to 1.10. In 28 children and adolescents (aged 4-17years), Rose and Helminski calculated VOR gain in horizontal and vertical SCCs in the range of 1.00-1.04 and 1.03-1.08, respectively [13], which were in accordance with our results.

This study is similar to Ulmer et al. [21] and Murnane et al. [15] studies, where the VOR gain for vertical SCCs, especially in posterior SCCs, was less than VOR gain for horizontal SCCs. The lower gain in VOR can be related to many factors such as lower amplitude of eye movement in vertical than horizontal plane, smaller visual range, and poorer resolution of camera in vertical than horizontal plane [15].

In the present study, there were no significant differences between the left and the right ears in VOR gain of SCCs, which was consistent with the results of previous research works [10,13-15,22]. Also, in a study performed by Janky and Givens [23] on 11 cochlear implanted and 12 normal children, no significant difference was reported between the right and the left VOR gain in each of SCCs, which was not consistent with our finding.

Our findings showed that there is no significant difference between VOR gain of right and left sides, whereas McGarvei et al. [8] reported a significant difference between VOR gain of right and left sides. A possible reason for this conflict may be the different procedures used in these two studies because, unlike our study that utilized both eye impulses in the measurement of horizontal SCCs, they only measured the right eye impulses. They believed that as the head rotates to the right side, the right eye rotation in the skull is greater than the left eye rotation. The opposite of this is true for the left eye; when measuring the left eye impulses, head rotation to the left side leads to more rotation of the left eye compared to the right eye. Therefore, measuring solely the right eye impulses can be a reason for the higher VOR gain of the right SCCs versus the left SCCs.

Our results also showed that there was no significant relationship between gender and VOR gain, which is in agreement with previous studies [19,24-26].

Due to the easy performance, shorter time to conduct, and being tolerable for children, by utilizing the normalized VOR gain data found in this study, one can probably perform vHIT as an assessment tool for the evaluation of balance skills in children. This test may be considered as a part of the protocol in the detection of vestibular problems in children.

Among the strengths of this study, we can note the similarity of statistical distribution of the subjects in terms of age and gender. On the other hand, the small sample size and narrow age range were the limitations of this study. Therefore, studies with larger sample size and wider age range groups are recommended.

Conclusion

The present study reports the VOR gain of SCCs in children. There are no differences in VOR gain between the right and left ears as well as between the genders. Also, the mean VOR gain of the horizontal SCCs was slightly higher than that of the vertical SCCs. The lower mean VOR gain of the vertical SCCs may be related to several factors such as lower eye movements in vertical than horizontal plane, smaller visual range, and poorer resolution of camera in vertical than horizontal plane.

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Conflict of interest

The authors declared no conflicts of interest.

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