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RESEARCH ARTICLE

A preliminary study of sinusoidal harmonic acceleration test results in 7-12 years old normal children

Faride Badfar[1], Marzieh Sharifian Alborzi[1*], Nima Rezazadeh[2], Alireza Akbarzade Baghban[3], Homa Zarrinkoob[1], Afrooz Pourfahimi[4]

[1]- Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[2]- Department of Audiology, University of Social Welfare and Rehabilitation, Tehran, Iran

[3]- Department of Basic Sciences, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[4]- Audiology Section, Comprehensive Rehabilitation Center of Red Crescent Organization of Islamic Republic of Iran, Tehran, Iran

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Abstract

Background and Aim: Sinusoidal harmonic acceleration (SHA) test is one of the most effective and best-tolerated methods to assess vestibular system function, especially horizontal semicircular canal in children. A prerequisite for using this test in children, is the availability of normative data. Despite of the numerous studies related to the SHA in adults, few researches have been documented in children. The aim of this study was to obtain normal values for SHA responses in normal children.

Methods: In this cross-sectional study, 38 children (20 boys and 18 girls) between 7 to 12 years old (mean age=9.55, SD=1.71) with normal hearing and no history of vestibular dysfunction were enrolled. SHA test was performed in five frequencies (0.01, 0.02, 0.08, 0.16 and 0.32 Hz) and fixation suppression test was performed in two frequencies (0.16 and 0.32 Hz). Parameters of gain, phase and symmetry in SHA test and fixation index (FI) in visual fixation suppression test in each frequency were recorded and compared tow genders.

Results: SHA responses and visual fixation suppression results were recorded in all children. Effect of frequency in each parameters of gain and phase were shown to have statistical significant differences, that is with increasing of frequency, gain increases and phase decreases ($p \leq 0/001$).

Conclusion: In this study normative values for SHA test and visual fixation suppression responses were proposed. These normative data can be used in the assessment of balance disorders and dizziness in school age children.

Keywords: Sinusoidal harmonic acceleration; suppression of the visual system; horizontal semicircular canal; 7-12-year normal children

Introduction

Children with dizziness and balance dysfunction have a complex diagnostic problem, therefore the vestibular assessment is required as a systematic approach. A prerequisite for using vestibular test results in children as a clinical tool is the availability of age-appropriate normative data [1]. Rotatory chair test also is one of the most effective and best-tolerated methods to assess vestibular system function in children [2]. This test was first introduced by

* **Corresponding author:** Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Damavand Ave., Tehran, 1616913111, Iran. Tel: 009821-77561724, E-mail: msharifian@sbmu.ac.ir

Barany. Then, Wolf et al. combined sophisticated electronics and computer technology to develop the sinusoidal harmonic acceleration (SHA) test [3]. SHA test provides quantitative evaluation of the vestibule-ocular reflex (VOR) function of the horizontal semicircular canals in ranges of frequencies [4]. SHA test is essential part of the vestibular battery test and can provide valuable clinical information in the evaluation and monitoring of patients with vertigo and dizziness, and those with neurological problems [5]. Some advantages of this test is the higher sensitivity (71% rotatory chair vs 31% electronystagmography) for detecting the loss of vestibular function [6]. Limitation of this test is low sensitivity in differentiating peripheral vestibular system from central dysfunction [4]. The visual suppression test is one method for examining the function of visual fixation and visual influence on vestibular nystagmus that indicate dysfunction in patients with cerebellar lesions [7].

Although the vestibular end organ is fully developed at birth, anatomically and functionally, the maturation of the VOR continues by developing central inhibitory influences, cerebellar control, and central vestibular adaptation reach adult developmental levels around the age of 15 years. Therefore, age-appropriate normative data are a prerequisite to analyze test results accurately to avoid misdiagnoses related to immature vestibular systems [1,8]. Despite of the numerous studies in adult age groups [9,10], few studies performed on the normative data in rotatory chair test especially SHA and visual fixation suppression tests in children. One of the related studies is Valente's in 2007 in age effect on maturation of the vestibular system responses, that showed, the result of vestibular test such as SHA (gain and phase) in two children groups (3-6 and 9-11 years old) comparing to adults. The results showed significant develpemental effects from preschool through adulthood and they suggest that using normative data of adults are not appropriate for interpreting children's results [11]. Casselbrant et al. obtained longitudinal normative data of SHA test in frequencies 0.02, 0.05, 0.1 and 0.5 Hz in children with normal middle ear status from 3 to 9 years. They observed a linear increasing in VOR gain as age increased, whereas there was no change in phase response [1]. Maes et al. did not observe the age-related differences in SHA test as they obtained normative data of SHA test in frequencies 0.01, 0.05 and 0.5 Hz for a group of children 4-12 years of age without any hearing and vestibular complaints [8]. Also, Aust investigated the effect of age on inhibition of visual fixation of rotatory-induced nystagmus. He showed that the amplitude of nystagmus evoked by SHA is suppressed by visual fixation, and the degree of suppression depends on age [12]. In fact, SHA test has important advantages such as it is non-invasive, and easily performed in children, horizontal semicircular canals are stimulated in a wide range of frequencies and provides information about vestibular-ocular system in this broad range, that will not be obtained by using videonystagmography (VNG) test. SHA test is so important that it is called vestibulogram [2].

There are few related studies in children, and no study is reported yet on the normative data of SHA test in frequencies ranged 0.01, 0.02, 0.08, 0.16 and 0.32 Hz in children, despite the different results obtained by investigation of the effect of age on SHA test results. The authors of the present study, evaluated SHA and fixation suppression test in children with age ranged 7 to 12 years old.

Methods

This cross-sectional study was performed on 38 children (20 boys and 18 girls), with age ranged 7-12 years old (mean=9.55, SD=1.719). Samples were selected randomly from Razi girls' elementary school and Shahid Beheshti boys' elementary school in Educational region 3 in Tehran. All subjects had normal hearing thresholds and had no history of vestibular disorders. In present study, patients with psychiatric disorders, movement and neurological disorders and any pathology in

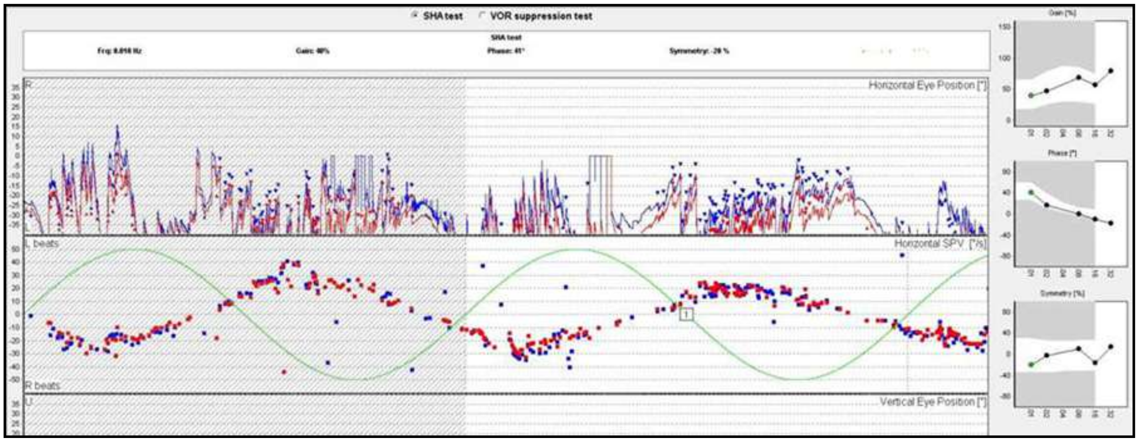

Fig. 1. sinusoidal harmonic acceleration response in different frequencies in one of the children.

middle and external ear, were excluded, since studies on patients with otitis media with effusion (OME) have reported increased vestibular disturbances and postural sway during dynamic posturography [13,14].

Current study was carried out at Rehabilitation Center of Red Crescent Organization in winter of 2014. We obtained written consent from parents of all subjects and all stages of this research were approved by research committee of Shahid Beheshti University of Medical Sciences.

In order to check the health of external, middle and inner ear, we have taken case history, and performed otoscopic examination, acoustic immittance audiometry with AZ26 and pure tone audiometry (PTA) in frequencies 250-8000 Hz with clinical audiometer AC40 (both from Interacoustic, Denmark) for all cases. Having a healthy tympanic membrane signs of otoscopy, type A tympanometry, normal contralateral and ipsilateral reflexes in frequencies 500-4000 Hz and AC and BC hearing thresholds below 15 dBHL in PTA considered as normal hearing. Individuals eligible for the study, after preparation were examined by SHA test.

SHA responses were recorded using rotatory chair apparatus Nydiagmodel (Interacoustic, Denmark). To record SHA responses the child is placed on a rotating seat, his/her head was fixed with 30 degree forward to best stimulate horizontal semicircular canals (SCC). As the rotatory chair is designed for adult evaluation we used a cushion specially designed for children to hold the child's head in appropriate position. The test was performed in total darkness. Eye movements were recorded by infrared cameras. The child was asked to do cognitive tasks such as naming objects during the test, so ocular responses did not suppress. After placing infrared cameras on children's eyes, before starting the test, we calibrated the child's ocular responses and angle of movement of the rotatory chair. The spontaneous nystagmus test was performed before the SHA test, to exclude the effect of spontaneous nystagmus on test results in slow phase symmetry. None of the children showed spontaneous nystagmus. The test was done at frequencies of 0.01, 0.02, 0.08, 0.16 and 0.32 Hz for each child. At first, the test was carried out in mid and then in low frequencies. Before testing each frequency, calibration was repeated. Maximum chair rotation velocity was set in 50 degrees per second. The maximum acceleration varied from 3 degrees per second at 0.01 Hz to 50 degrees per second at 0.16 Hz. To evaluate each of parameters, we performed two sinusoidal full cycle rotations at low frequencies (0.01) and eight cycles at the higher frequencies. Parameters of gain, phase and symmetry was calculated for both sides of rotation for all frequencies. To investigate the effect of visual fixation during rotation, the test was repeated at

Table 1. Mean (SEM) phase, gain, symmetry and percent gain reduction in SHA and visual fixation suppression test in normal hearing children

			Mean (SEM) in different frequencies (Hz)				
variable	**Sex**	**Number**	**0.01**	**0.02**	**0.08**	**0.16**	**0.32**
Phase	**f**	**18**	49.27 (2.16)	28.55 (1.24)	4.72 (1.41)	-4.50 (1.60)	-12.38 (2.76)
	m	**20**	47.85 (1.95)	25.85 (1.47)	5.00 (1.53)	-5.40 (2.76)	-15.25 (2.79)
Gain	**f**	**18**	35.66 (1.60)	46.22 (2.49)	62.11 (4.28)	72.72 (4.11)	75.22 (4.10)
	m	**20**	42.55 (3.30)	51.75 (2.25)	66.15 (3.51)	70.65 (3.43)	76.30 (3.73)
Symmetry (%)	**f**	**18**	-1.38 (3.17)	3.00 (3.84)	2.22 (2.86)	4.77 (2.80)	4.83 (3.23)
	m	**20**	-3.55 (4.08)	0.05 (1.59)	-2.30 (2.65)	-2.10 (2.44)	-1.85 (2.54)
Percent gain reduction	**f**	**18**	-	-	-	71.61 (2.32)	72.27 (3.12)
	m	**20**	-	-	-	69.10 (2.53)	65.00 (2.68)

f; female, m; male

frequencies of 0.16 and 0.32 Hz. The individuals were asked do not have any mental activity and when they were rotating, they were asked to fix their gaze on a laser target in front of them that was rotating with the chair. Fixation index (FI) was calculated in these two frequencies.
Data were analyzed using SPSS 20 at significant level of $p \leq 0.05$. We used mean ±SEM for descriptive statistics and Kolmogorov-Smirnov test to evaluate normal distribution of data. All variables had normal distribution. To study the effects of gender, frequency and the interactions of gender and frequency in variables of gain, phase, symmetry and FI, ANOVA test with repeated measures was used. Pearson test was used to determine the correlation between age and gain, phase, symmetry and FI at each of the used frequencies.

Results
SHA and visual fixation suppression test results were recorded for all children. An example of response of a child during rotation of chair is shown in Fig. 1. Also results of SHA and visual fixation suppression tests for each of the two genders (18 girls and 20 boys) are shown in Table 1, separately. According to Table 1, the mean symmetry was between -55.3 and +83.4. Also, the mean FI in frequencies 0.16 and 0.32 Hz in girls were 71.61 and 72.27, and in boys were 69.10 and 65.00, respectively.
Studying the effect of frequency on each of the parameters examined in present study showed no statistically significant differences in phase and gain. As shown in Table 2, and Table 1, increment of frequency caused, phase decrement, but gain was increased ($p \leq 0.001$). Effect of frequency on symmetry and FI did not show any statistically significant correlation.
Comparing the results of the two genders (Table 2) showed no statistically significant differences in any of the parameters (gain, phase, symmetry and FI) between boys and girls ($P \geq 0.09$). Study of interactive effects of gender and frequency in all variables did not show any significant correlation between age and the scores of each of variables in each of the frequencies ($p \geq 0.05$). Pearson correlation coefficients for each of the variables at different frequencies are shown in Table 3.

Discussion
To the extent that we have searched, it was the

Table 2. Effects of frequency and sex, and their interactions on each variable

	Phase		Gain		Symmetry		Percent gain reduction	
	p	power	p	power	p	power	p	power
Frequency main effect	0.001	1.0	0.001	1.0	0.45	0.23	0.36	0.14
Sex main effect	0.39	0.13	0.45	0.11	0.09	0.40	0.15	0.30
Interaction effect of frequency on sex	0.87	0.10	0.20	0.40	0.79	0.11	0.21	0.23

first time that SHA and fixation suppression tests were coducted in the entire range of rotation frequencies.

Present research is reporting the mean values of gain, phase, symmetry and FI in various frequencies in children. This research findings show that none of the studied parameters would change as a function of age. Various studies have reported the normal response to sinusoidal rotation in children with age range under one year to 16 years old. Cry et al. assessed SHA in frequency 0.08 Hz in children with three months of age to six years old. They found that the VOR gain would not change as a function of age [15] that is in line with the findings of the present study. Also, Valente et al. conducted SHA test in two rotation frequencies of 0.08 and 0.05 Hz in two age groups of preschool and school children. Although they did not found significant differences in phase, gain and symmetry measures between the two groups, but the gain scores in children was significantly higher than that of normal adults. These findings are consistent with the results of the present study [11]. Casselbrant et al. found contradictory results compared to the present study's findings, as they showed a linear increase in VOR gain at all tested frequencies. No change in phase at frequencies of 0.02, 0.05 and 0.1 Hz and decrease of phase at frequency 0.5 Hz with increasing the age was observed [1]. They concluded that, obviously there is no simple explanation for the differences between the results that we obtained and the other researchers' findings. probably due to the limitations of sample size, differences in the frequency of rotation and children of different ages. They also conducted another longitudinal study to evaluate SHA responses on 3-9 years old children. In their study, the largest changes were reported between 3 to 6 years. The reason was that however, the development of vestibular end organs and myelination of vestibular afferents are completed at birth, but maturation of the VOR continues until after birth. Many of the parameters of the VOR change throughout childhood but vestibular system is adult-like by 7.5 years old [16]. That could be there as on, why we did not find any significant difference as a function of age in our study.

Aust, evaluated age-related changes in visual fixation suppression test established by rotatory stimulation consisted of a sinusoidal stimulus pattern with amplitudes of ±180 degrees and a duration of 20seconds. They found that the degree of suppression depends on age. The trend to better fixation suppression increases up to 40, after that, the ability to suppress vestibular nystagmus decreases [12]. Disagreements of the present study might be due to differences in the frequency of rotation, limitation on the number of samples, and preliminary unreliable results. Accordingly a study with larger sample size is suggested. Also, comparison between two genders in each of parameters of gain, phase, symmetry at each of frequencies did not show significant differences. This finding is similar to results of Casselbrant et al. [1].

Conclusion

No changes were observed in each of

Table 3. Pearson correlation between variables in each frequency and age

variable		Frequency (Hz) 0.01	0.02	0.08	0.16	0.32
Phase	PCC	0.278	0.059	--0.305	0.119	--0.253
	p	0.091	0.726	0.062	0.479	0.126
Gain	PCC	0.117	0.140	0.095	-0.074	0.043
	p	0.484	0.401	0.569	0.659	0.796
Symmetry	PCC	-0.038	0.227	-0.071	0.136	0.060
	p	0.820	0.171	0.671	0.416	0.718
Percent gain reduction	PCC	-	-	-	0.133	0.072
	p	-	-	-	0.425	0.666

PCC; Pearson correlation coefficient

parameters of SHA and visual fixation suppression tests as a function of age and gender. SHA can be used alone or along with other conventional vestibular tests as a useful diagnostic tool to evaluate the performance of the vestibular system in children. Due to limitation on the number of samples and the preliminary unreliable results, a study with larger sample size is recommended.

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