Original Article

https://doi.org/10.1590/2317-6431-2019-2209

Audiology Communication Research
ISSN 2317-6431

Evaluation of the influence of aging on vestibular function by the video Head Impulse Test (v-HIT)

Avaliação do efeito da idade sobre a função vestibular por meio do Teste do Impulso Cefálico (v-HIT)

Marlon Bruno Nunes Ribeiro[1], Ligia de Oliveira Gonçalves Morganti[2], Patricia Cotta Mancini[3]

ABSTRACT

Purpose: to evaluate the effect of age on vestibular-ocular reflex gain through v-HIT. **Methods:** this was a cross-sectional, analytical, observational study conducted with 90 subjects without self-reported otoneurological alterations, who underwent v-HIT examination in order to evaluate semicircular canal gain and cephalic pulse velocity. **Results:** the age of the sample ranged from 20 to 83 years. It was decided that the sample be divided into three age groups to facilitate the analysis: 18 to 30 years; 31 to 59 years, and over 60 years old. A decrease in vestibular-ocular reflex gains of the right and posterior semicircular canals was observed with increasing age. The average semicircular canal gain was close to one and the velocities above 100º/s. **Conclusion:** the average gain of the semicircular canals is within the normality standards found in the literature. Only the posterior and right anterior semicircular canals showed reduced gain with increasing age.

Keywords: Ear, Inner; Semicircular canals; Saccades; Postural balance; Aging

RESUMO

Objetivo: avaliar o efeito da idade sobre o ganho do reflexo vestíbulo-ocular por meio do v-HIT. **Métodos:** estudo transversal, analítico, observacional, realizado com 90 indivíduos sem alterações otoneurológicas autorrelatadas, que foram submetidos ao exame v-HIT, com o intuito de avaliar o ganho dos canais semicirculares e a velocidade dos impulsos cefálicos. **Resultados:** a idade da amostra variou de 20 a 83 anos. Optou-se pela divisão em três faixas etárias para facilitar a análise: 18 a 30 anos; 31 a 59 anos e maior que 60 anos. Houve diminuição dos ganhos do reflexo vestíbulo-ocular dos canais semicirculares anterior direito e posteriores com o aumento da idade. As médias do ganho dos canais semicirculares foram próximas a 1 e as velocidades, acima de 100º/s. **Conclusão:** as médias do ganho dos canais semicirculares estiveram de acordo com os padrões de normalidade da literatura. Apenas os canais semicirculares posteriores e o anterior direito apresentaram redução do ganho com o aumento da idade.

Keywords: Orelha interna; Canais semicirculares; Movimentos sacádicos; Equilíbrio postural; Envelhecimento

Study carried out at Departamento de Fonoaudiologia, Faculdade de Medicina, Universidade Federal de Minas Gerais – UFMG, Belo Horizonte (MG), Brasil.
[1]Faculdade de Medicina, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brasil.
[2]Hospital São Geraldo, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brasil.
[3]Departamento de Fonoaudiologia, Faculdade de Medicina, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brasil.
Conflict of interests: No.
Authors' contribution: MBNR participated in the study design, data collection, analysis and interpretation, and article writing; LOGM participated in data collection, analysis and interpretation, article writing and study coorientation; PCM participated, as advisor, in the idealization of the study, analysis and interpretation of data, and article writing and review.
Funding: None.
Corresponding author: Patricia Cotta Mancini. E-mail: patmancini@gmail.com
Received: June 26, 2019; **Accepted:** October 28, 2019

This is an open-access article distributed under the terms of the Creative Commons Attribution License.

INTRODUCTION

The labyrinth, or inner ear, is a peripheral sensory organ composed of an anterior portion, known as the cochlea, responsible for hearing, and a posterior portion, accountable for detecting head movement and orientation of the head in relation to gravity. The organ has a bony layer, which covers it externally, and an inner membrane layer that contains sensory structures. Each labyrinth is comprised of three semicircular canals (SCCs) responsible for detecting angular head movements and two otolithic organs for detecting linear movements. These canals are arranged in perpendicular planes and reach orthogonal coverage of the three dimensions of space[1,2].

Functionally, the SCCs work in synergistic pairs, one on each side, situated on the same plane of space. An excitatory stimulus in one canal generates an inhibitory stimulus in its pair and vice versa. The lateral canals, also referred to as 'horizontal' canals, form a pair and are at an angle of thirty degrees in relation to the horizontal plane. The right anterior and left posterior canals are located in the same space plane, forming another synergic pair, as well as the left anterior and right posterior canals[1-4].

In healthy individuals, SCCs detect angular accelerations performed by the head, sending the extrinsic eye muscles the necessary stimuli to produce compensatory movement of the eyeball in the same direction and in the opposite direction, in a way that stabilizes the retinal image[1-4].

This mechanism constitutes the vestibular-ocular reflex (VOR), one of the fastest reflexes in the body, which is formed by only three neurons: vestibular ganglion, vestibular nucleus, and ocular motor nuclei; with a latency of only 7 to 10 milliseconds[1,4,5]. In the presence of semicircular canal hypofunctio, during movement, the eye moves along with the head, away from the target. Subsequently, it performs a corrective saccade to return to the target[1,4-7].

Individuals with impaired vestibular function, who present consequent VOR deficits, need to perform corrective eye movement to reach the target after a cephalic movement. This movement, denominated 'corrective saccade', can occasionally be seen with the naked eye (OVERT saccades). However, there are corrective saccades that occur with short latency, in a way that they cannot be observed without the aid of specific examination (COVERT saccades)[4,8-11].

In 1963, Robinson designed a scleral search-coil magnetometer (SCM), which is still considered the gold standard for dimensionally recording eye and head movements. This technique allows VOR recording during head impulses, enabling the study of the eye rotation axis, gains, asymmetry, and latencies triggered by head rotations in the SCC functional pair planes. It should be noted that, despite its usefulness, it is an uncomfortable, expensive, invasive, and difficult-to-implement clinical method for the patient. However, in 1988, Halmagyi and Curthoys created the video head impulse test (v-HIT), the computerized version of the head impulse test (HIT). Thus, the v-HIT constitutes a rapid, objective, and comfortable otoneurological evaluation of the individuals submitted to it[6-10,12].

The video head impulse test (v-HIT) is a fast and objective evaluation that assesses the VOR in each semicircular canal individually and at a physiological frequency of angular head acceleration through rapid, short-range cephalic pulses. At each pulse, the v-HIT provides the record of head movement and the reflex response of the eye. Impulsive tests are quick to trigger VOR without cortical or slow ocular system contamination[4,5,9,10].

Recording eye and cephalic velocity profiles during cephalic pulse by v-HIT allows the calculation of VOR gain, defined as the ratio between these velocities. This ratio can be calculated at specific times (at 40, 60, and 80 minutes), after impulse onset (instantaneous gain), or as a result of linear regression (regression gain). The latter seems to be the most robust value, while the former enables the evaluation of the dynamic variation of VOR gain during the pulse. Given the existence of latency and, therefore, discrepancies between the cephalic and ocular velocity curves, the obtained normalization values are slightly lower (0.95 ± 0.09)[4,5].

When calculating the normal limits of VOR gain, some authors reported values ranging from 0.77 to 1.33[4,5]. In order to obtain higher values, poor calibration or excessive proximity to the target should always be assessed, thus revealing the importance of a minimum distance of one meter between the individual and the target. The VOR gain evaluation enables the calculation of interaural asymmetry[4-6].

Studies have revealed evidence of vestibular receptor cell loss and primary afferences with increasing age, as there is a considerable decrease in receptors in each semicircular canal, suggesting a decline in VOR with aging[7,11,13]. Some authors found a small decrease in VOR gain in vertical canals[7,11,13]. Thus, data from individuals without otoneurological changes are necessary in order to assess how the gain of VOR is affected by age.

According to the World Health Organization (WHO), the elderly are individuals aged 60 years or older[14]. Aging is a natural process of progressive reduction of an individuals' functional reserve[15], which generates physical, psychological, and social consequences, and may affect functionality and increase the risk of falling[16].

Some studies seek to standardize SCC gain through v-HIT, but there are still controversies in the literature regarding the decrease in gain with age. Thus, the aim of the present study was to evaluate the influence of age on semicircular canal gain through v-HIT.

METHODS

The procedures conducted in this study were approved by the Research Ethics Committee of the Federal University of Minas Gerais (CEP-UFMG), under protocol No. CAAE 56877316.1.0000.5149 (according to Resolution CNS 466/12). The research was carried out at the Observatory of Functional Health in Speech Therapy of the Department of Speech Therapy of the School of Medicine of the Federal University of Minas Gerais – UFMG - Minas Gerais (MG), Brazil.

The sample consisted of 90 individuals, without previous self-reported otoneurological alterations in a questionnaire. Individuals older than 18 years of age, who voluntarily agreed to participate in the study, and who had normal otoscopy, no history of surgery or otological trauma, no previous self-reported vestibular diseases or difficulties in cervical execution, and that signed an Informed Consent form were included. It was considered a convenience sample, composed of individuals from the academic community (students, faculty, and University staff). The elderly participants are part of a program called "City Academy", which takes place at the building of the UFMG School of Medicine.

At first, the participants answered a questionnaire containing demographic information (age and gender) and data regarding otological and vestibular history to verify the absence of possible auditory or vestibular alterations. The v-HIT exam was performed by the same researcher using ICS-Impulse equipment from Otometrics®. No other otoneurological examination was conducted.

In order to perform the exam, each participant remained seated in a chair at 120 cm from the target, with the equipment mask well-adjusted to the head, thus minimizing possible slips. After calibrating the eye position signal, the participants were instructed to fix their gaze on a target located on the wall at eye level while the examiner performed the cephalic pulses in the specific stimulation planes of the six semicircular canals. At least 20 pulses were obtained from each canal, with a maximum of ten pulses rejected by the device as inappropriate.

Meanwhile, in order to evaluate the lateral canals, short and fast movements were performed with the participant's head to the right and left at random. When assessing the vertical canals, the participant's head was moved 45° to the right of the median plane of the head, placing the left anterior and right posterior (LARP) canals in the same plane of stimulation. In this position, forward head movement activates the left anterior canal and backward movement activates the right posterior canal. Next, the participant's head was positioned at this same angle but to the left, evaluating the synergistic pair of the right anterior and left posterior semicircular canals (RALP). In this position, forward head movement stimulates the right anterior canal, and backward movement activates the left posterior canal. Unpredictable frequency and direction movements of low amplitude (10-20°) and high acceleration (1,000-2,500°/s^2) and velocity (100-250°/s) were performed, as required by the equipment manual[17]. The duration of the exam was of approximately 15 minutes.

The equipment features sensors that detect and measure head and eye movements. For each movement performed by the examiner (pulse), two sinusoids are plotted, represented in graphs, resulting from head and eye movement. In healthy individuals, the graphics are expected to be equal, resulting in the so-called 'gain equal to 1'. When eye movement is less than head movement, this results in a gain below 1, and the compensatory movement of the eyes - corrective saccade - is carried out to bring the eyes back to the target. The exam was validated, and gains greater than or equal to 0.8 for the lateral canals and 0.75 for the vertical canals are considered normal[9,10] (Figure1).

The v-HIT results were evaluated regarding gain, presence of corrective saccades, and the velocities at which each canal was tested. The collected data were entered into an Excel table and

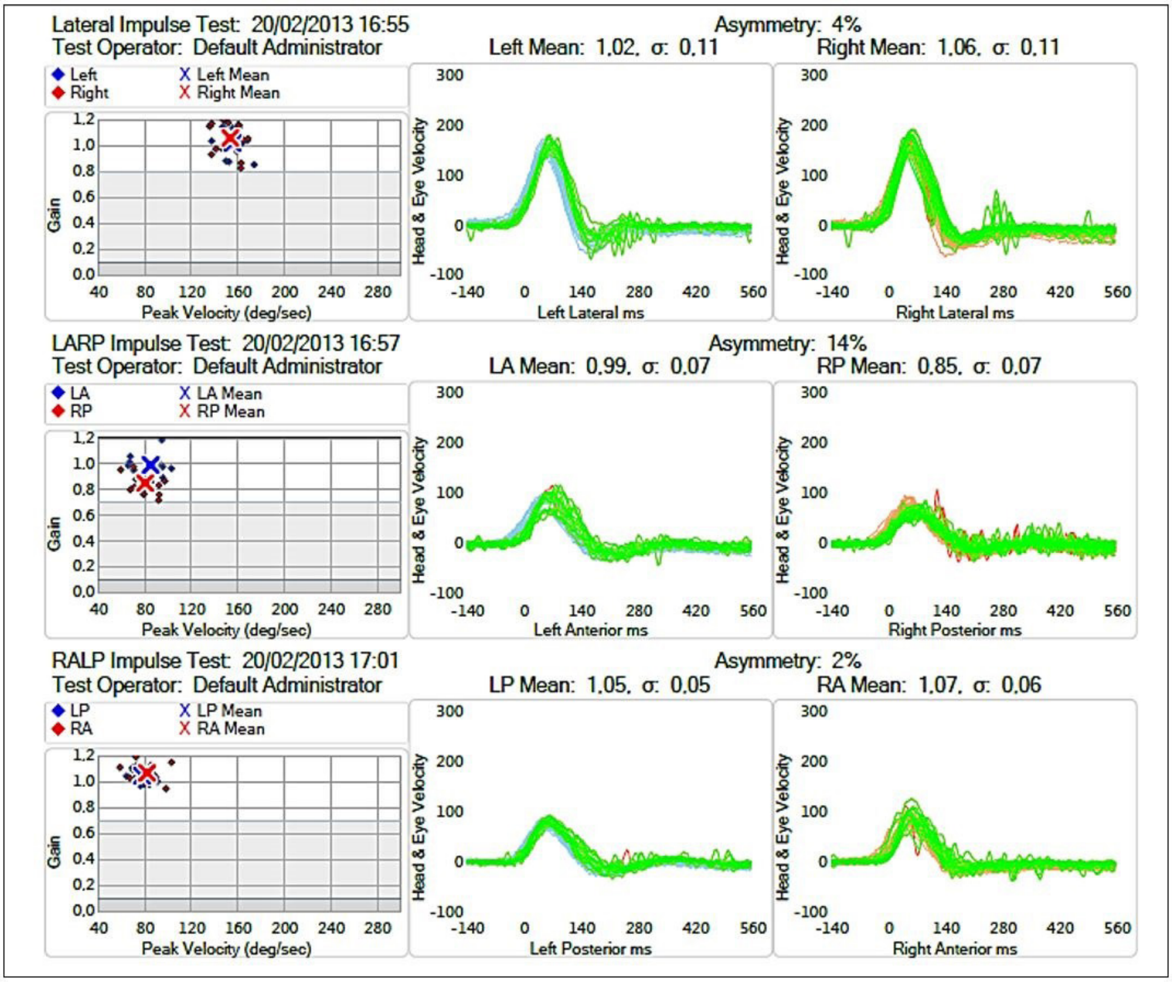

Figure 1. Result within normal limits (personal file)
Subtitle: LARP = left anterior and right posterior canals; RALP = right anterior and left posterior canals; LP = left posterior semicircular canal; RP = right posterior semicircular canal; LA = left anterior semicircular canal; RA = right anterior semicircular canal

submitted to statistical analysis, performed using the Statistical Package for Social Sciences (SPSS), version 22.0.

Initially, a descriptive analysis of the frequency of the age and gender variables was conducted. Measurements of central tendency (mean and median), dispersion (standard deviation), and position (maximum and minimum) of the continuous variables (age, semicircular canal gain, and cephalic pulse velocity) were analyzed. The normality of the continuous variables was observed using the Kolmogorov-Smirnov test. Correlations between the age and gain of the SCC were analyzed using the Jonckheere-Terpstra test, which considers sample ordering. Also, a significance level of 5% ($p<0.05$) was adopted in all analyses.

RESULTS

Age ranged from 20 to 83 years, with a mean of 46.4 years and a standard deviation of 19.8 years. The most prevalent sex was female, with 84.4%, while males comprised 16.6% of the sample. When analyzing the age of the subjects in categories, the following proportions were obtained: 31 young people up to 30 years old (34.1%), 31 adults aged 31 to 59 years (35.2%), and 28 elderly (30.7%) over 60 years of age. The mean SCC gain ranged from 0.87 to 1.05, and the mean velocity varied between 122º/s and 180º/s. The central tendency values for the six semicircular canal gains and exam velocity can be observed in Table 1.

In order to analyze the association of the semicircular canal gain with age, we decided to divide the ages into three categories (up to 30 years, 31 to 59 years, and >= 60 years). The lateral (right and left), anterior (right and left), and posterior (right and left) canals were averaged. A statistical difference was observed only when comparing the VOR gain in the posterior semicircular canals (Table 2).

To better illustrate the difference found in posterior canal gain, a graph was elaborated, showing the relationship between semicircular canal gains and increasing age (Figure 2).

The outliers were analyzed and showed no confusion in the selection. The exams were reliable, and the rest of the sample was not influenced since age is a variable without normal distribution, analyzed by a nonparametric test.

Pearson's correlation between age and SCC gain was also analyzed. Significance was found between increasing age and decreased right anterior (R -0.21; p 0.045) and left posterior (R -0.82; p 0.007) SCC gain, but the correlation was statistically low (Figures 3 and 4).

Analysis of the correlation between the speeds of the head impulses and the SCC gain was also performed. Significance was observed only between the right (R-0.357; p-0.001) and left (R-0.26; p-0.010) lateral canals, suggesting that the higher the velocity, the lower the SCC gain. The analysis of the correlation between sex and gain did not present a statistical difference.

Table 1. Measures of central tendency and dispersion of the gain of semicircular canals and movement speed performed during the exam (N = 90)

Semicircular canal	Gain of semicircular canals					Speed of movement (100-250º/sec)				
	Mean	SD	Median	Mín	Max	Mean	SD	Median	Mín	Max
Left lateral	0.96	0.13	0.93	0.64	1.42	180.00	24.08	180.0	120	240
Right lateral	1.05	0.12	1.00	0.76	1.52	169.67	24.05	160.0	120	240
Left anterior	0.96	0.14	0.94	0.71	1.59	122.97	11.42	120.0	90	180
Right anterior	0.90	0.15	0.89	0.59	1.34	125.16	13.42	120.0	110	160
Left posterior	0.87	0.15	0.88	0.44	1.31	130.71	10.12	130.0	110	160
Right posterior	0.88	0.13	0.87	0.41	1.46	128.02	13.20	120.0	110	180

Subtitle: SD = standard deviation; Min = minimum value; Max = maximum value; N = number of participants; sec = seconds

Table 2. Comparison between participants' age and semicircular canal gain (N = 90)

Gain of Semicircular canals	Age (years)	Mean	SD	Median	Min	Max	P-value*
Lateral							
	18 to 30	1	0.11	0.98	0.87	1.31	
	31 to 59	0.99	0.1	0.96	0.88	1.39	0.977
	≥ 60	1.01	0.16	0.98	0.7	1.47	
Anterior							
	18 to 30	0.95	0.14	0.95	0.74	1.46	
	31 to 59	0.93	0.13	0.91	0.66	1.32	0.086
	≥ 60	0.9	0.1	0.9	0.77	1.1	
Posterior							
	18 to 30	0.92	0.13	0.93	0.69	1.39	
	31 to 59	0.86	0.11	0.88	0.54	1.18	**0.036***
	≥ 60	0.84	0.13	0.84	0.55	1.08	

*Jonckheere-Terpstra Test

Subtitle: SD = standard deviation; Min = minimum value; Max = maximum value; N = number of participants

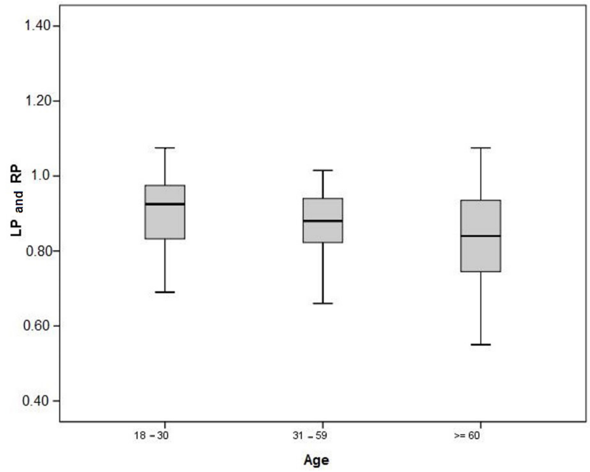

Figure 2. Boxplot of posterior semicircular canals' gain with increasing age, in three categories
Subtitle: LP = left posterior semicircular canal; RP = right posterior semicircular canal

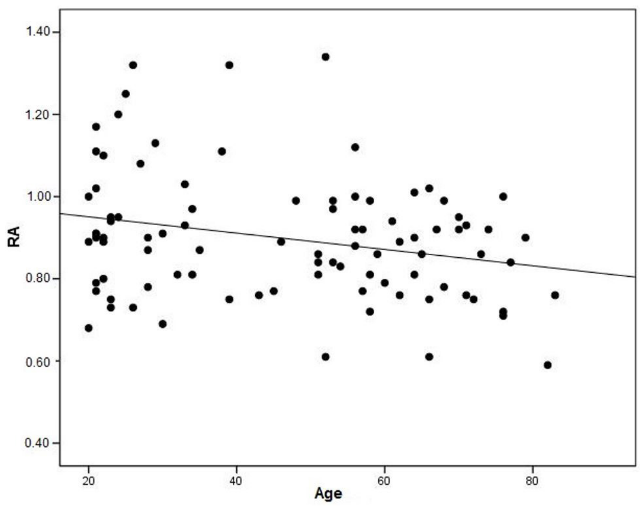

Figure 3. Scatter plot of right anterior semicircular canal gain with increasing age
Subtitle: RA = right anterior semicircular canal

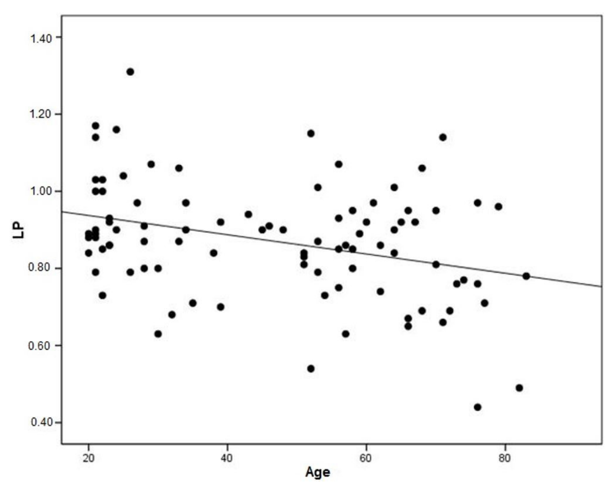

Figure 4. Gráfico de dispersão do ganho do canal semicircular posterior esquerdo com o aumento da idade
Subtitle: LP = left posterior semicircular canal

DISCUSSION

In the present study, the mean age of the sample was 46.4 years, with females being the most prevalent. Although it was a convenience sample, the characteristics of the assessed group may favor future comparative studies, since, according to the literature, dizziness is more frequent in women over 40 years of age[3-6,13,18,19].

No calculation was performed to define the age groups, considering individuals aged 60 years or older as elderly, according to the World Health Organization (WHO) [14]. The young and adult groups were divided so as to maintain an approximate percentage of individuals in each group: young people (34%) and adults (35%).

The gains of all the semicircular canals presented means close to 1, thus confirming the findings of other studies where healthy individuals were evaluated[7,11,13,18-20]. Mossman et al.[21] also reported gain values near 1 in 60 individuals without otoneurological alterations.

Therefore, the present study contributes to the provision of data for future comparisons in research to be conducted with individuals without vestibular alterations in a diverse age range. It also reveals the importance of considering lower gains for older individuals.

In the comparison between age groups, only the gain of the posterior semicircular canals differed with increasing age, a fact that corroborates the study by Matino-Soler et al.[7], who also found a decrease in right and left posterior canal gain with increasing age. This result reaffirms the hypothesis that aging can considerably decrease semicircular canal receptors[22-24]. As of age 40, it is possible to observe microscopic synaptic alterations in the vestibular nerve; at age 50, the degeneration of vestibular receptors on the crests of the SCC and the saccule. As of age 60, there is increased friction of vestibular nerve fibers and a reduction in the conduction velocity of electrical stimulation in the vestibular nerve, which may alter its function and reflexes, such as VOR[23-25].

The mean velocity was near 100 degrees per second in the vertical semicircular canals and close to 200 degrees per second in the lateral semicircular canals, as expected in the equipment manual for reliable examination[26]. When analyzing the correlation between head pulse velocities and SCC gain, it was found that increased pulse velocity in lateral SCCs ensured smaller gains, confirming the findings that increased velocity fosters low SCC gains[11,13,17,21,27,28,29].

Saccades were not present in the study groups, a fact that agrees with the literature since the saccades reveal labyrinth hypofunction and are considered signs of pathology[1,2,4,5,13,17-19,27,28,29].

The elderly who comprised the study sample came from the City Academy Program, an initiative of the Ministry of Health. Therefore, the studied group may present a different profile from the elderly population in general, which hinders generalizations beyond the sample[30]. Thus, the results found in the present study refer to healthy elderly people who regularly practice physical activity.

One of the difficulties found during the v-HIT examination with the elderly was the occurrence of eyelid ptosis, which led to the use of strategies that facilitated pupil capture by the device's camera. Thus, adhesive tapes were used in the transverse direction of the eyebrows in order to lift the eyelids of the individuals.

CONCLUSION

The mean semicircular canal gains and the mean velocities of the cephalic pulses were within the normal range. The posterior and right anterior semicircular canals decreased in gain with increasing age.

REFERENCES

1. Cremer PD, Halmagyi G, Aw S, Curthoys IS, McGarvie LA, Todd MJ, et al. Semicircular canal plane head impulses detect absent function of individual semicircular canals. Brain. 1998;121(4):699-716. http://dx.doi.org/10.1093/brain/121.4.699. PMid:9577395.
2. Halmagyi GM, Curthoys I, Cremer P, Henderson CJ, Todd MJ, Staples MJ, et al. The human horizontal vestibulo-ocular reflex in response to high-acceleration stimulation before and after unilateral vestibular neurectomy. Exp Brain Res. 1990;81(3):479-90. http://dx.doi.org/10.1007/BF02423496. PMid:2226683.
3. Wuyts F. Principle of the head impulse (thrust) test or Halmagyi head thrust test (HHTT). B-ENT. 2008;4:23-5.
4. Luís LA. Evaluation of central and peripheral vestibular patients with the video-head impulse test [doutorado]. Porto: Instituto de Ciências da Saúde, Universidade Católica Portuguesa; 2015.
5. Maia FCZ, Albernaz PLM, Carmona S. Otoneurologia atual. Revinter. 2014;1(5):89-119.
6. Halmagyi GM, Chen L, MacDougall HG, Weber KP, McGarvie LA, Curthoys IS. The video head impulse test. Front Neurol. 2017;8:258. http://dx.doi.org/10.3389/fneur.2017.00258. PMid:28649224.
7. Matiño-Soler E, Esteller-More E, Martin-Sanchez JC, Martinez-Sanchez JM, Perez-Fernández N. Normative data on angular vestibulo-ocular responses in the yaw axis measured using the video head impulse test. Otol Neurotol. 2015;36(3):466-471. http://dx.doi.org/10.1097/MAO.0000000000000661. PMid:25473958.
8. McCaslin DL, Jacobson GP, Bennett ML, Gruenwald JM, Green AP. Predictive properties of the video head impulse test: measures of caloric symmetry and self-report dizziness handicap. Ear Hear. 2014;35(5):e185-91. http://dx.doi.org/10.1097/AUD.0000000000000047. PMid:24801960.
9. MacDougall HG, Weber KP, McGarvie LA, Halmagyi GM, Curthoys IS. The video head impulse test: diagnostic accuracy in peripheral vestibulopathy. Neurology. 2009;73(14):1134-41. http://dx.doi.org/10.1212/WNL.0b013e3181bacf85. PMid:19805730.
10. MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP. Application of the video head impulse test to detect vertical semicircular canal dysfunction. Otol Neurotol. 2013;34(6):974-9. http://dx.doi.org/10.1097/MAO.0b013e31828d676d. PMid:23714711.
11. McGarvie LA, Halmagyi M, Curthoys I, MacDougall H. The video head impulse test (vHIT) of semicircular canal function – age-dependent normative values of VOR gain in healthy subjects. J Vestib Res. 2014;24:77-100.
12. Riska KM, Murnane O, Akin FW, Hall C. Video Head Impulse Testing (vHIT) and the assessment of horizontal semicircular canal function. J Am Acad Audiol. 2015;26(5):518-23. http://dx.doi.org/10.3766/jaaa.14083. PMid:26055841.
13. Tae Hwan K, Min-BeomHwa K. Effect of aging and direction of impulse in video head impulse test. Laryngoscope. 2018;128:228-33.
14. OMS: Organização Mundial da Saúde. Envelhecimento ativo: uma política de saúde. Brasília: Organização Pan Americana da Saúde; 2005 [citado em 2019 Jun 26]. Disponível em http://bvsms.saude.gov.br/bvs/publicacoes/envelhecimento_ativo.pdf
15. Pereira KCR, Lacerda JT, Natal S. Avaliação da gestão municipal para as ações da atenção à saúde do idoso. Cad Saude Publica. 2017;33(4):e00208815. http://dx.doi.org/10.1590/0102-311x00208815.
16. Fiorio GO. Functionality and risk of falls of elderly participants of a companionship group of Flores da Cunha, RS. PAJAR - Pan American. J Aging Res. 2018;6:50-7.
17. Janky KL, Patterson J, Shepard N, Thomas M, Barin K, Creutz T, et al. Video Head Impulse Test (vHIT): the role of corrective saccades in identifying patients with vestibular loss. Otol Neurotol. 2018;39(4):467-73. http://dx.doi.org/10.1097/MAO.0000000000001751. PMid:29533335.
18. Janky KL, Patterson JN, Shepard NT, Thomas MLA, Honaker JA. Effects of device on video Head Impulse Test (vHIT) gain. J Am Acad Audiol. 2017;28(9):778-85. http://dx.doi.org/10.3766/jaaa.16138. PMid:28972467.
19. McGarvie LA, MacDougall HG, Halmagyi GM, Burgess AM, Weber KP, Curthoys IS. The video head impulse test (vHIT) of semicircular canal function – age dependent normative values of VOR gain in healthy subjects. Front Neurol. 2015;6(1):154. http://dx.doi.org/10.3389/fneur.2015.00154. PMid:26217301.
20. Oiticica J, Bittar RS. Estudo epidemiológico populacional da prevalência de tontura na cidade de São Paulo. Rev Bras Otorrinolaringol (Engl Ed). 2015;81:167-76. http://dx.doi.org/10.1016/j.bjorl.2014.12.004.
21. Mossman B, Mossman S, Purdie G, Schneider E. Age dependent normal horizontal VOR gain of head impulse test as measured with video-oculography. J Otolaryngol Head Neck Surg. 2015;44:29. PMid:26141721.
22. Ganança FF, Gazzola JM, Aratani MC, Perracini MR, Ganança MM. Circunstâncias e consequências de quedas em idosos com vestibulopatias crônicas. Rev Bras Otorrinolaringol (Engl Ed). 2006;72(3):388-93. http://dx.doi.org/10.1590/S0034-72992006000300016.
23. Scherer S, Lisboa HRK, Pasqualotti A. Tontura em idosos: diagnostico otoneurológico e interferência na qualidade de vida. Diagnóstico Otoneurológico. 2012;17(1):142-50. http://dx.doi.org/10.1590/S1516-80342012000200007.
24. Simoceli L, Bittar RMS, Bottino MA, Bento RF. Perfil diagnóstico do idoso portador de desequilíbrio corporal: resultados preliminares. Rev Bras Otorrinolaringol. 2003;69(6):772-7. http://dx.doi.org/10.1590/S0034-72992003000600008.
25. Agrawal Y, Zuniga MG, Davalos-Bichara M, Schubert MC, Walston JD, Hughes J, et al. Decline in the semicircular canal and otolith function with age. Otol Neurotol. 2012;33(5):832-9. http://dx.doi.org/10.1097/MAO.0b013e3182545061. PMid:22699991.
26. GN Otometrics A/S. ICS Impulse USB - reference manual. 2019 [citado em 2019 Jun 26]. Disponível em http://madsen.hu/pdf/utmutato/Impulse_3.0_Reference_Manual_7-50-2040-EN_01.pdf
27. Sabour S. Diagnostic value of video head impulse test in vestibular neuritis: methodological issues. Otolaryngol Head Neck Surg. 2018;159(2):400-400. http://dx.doi.org/10.1177/0194599818779792. PMid:30066617.
28. Hougaard DD, Abrahamsen ER. Functional testing of all six semicircular canals with video head impulse test systems. J Vis Exp. 2019;(146):e59012. http://dx.doi.org/10.3791/59012. PMid:31058885.
29. Alhabib SF, Saliba I. Video head impulse test: a review of the literature. Eur Arch Otorhinolaryngol. 2017;274(3):1215-22. http://dx.doi.org/10.1007/s00405-016-4157-4. PMid:27328962.
30. Brasil. Ministério da Saúde. Portaria nº 719, de Abril de 2011. Institui o Programa Academia da Saúde no âmbito do Sistema Único de Saúde. Diário Oficial da União; Brasília; 08 abr 2011.