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Original Research

Vestibulo-Ocular Reflex in the Aging Population

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Abstract

Objectives: The aim of this study was to evaluate vestibulo-ocular reflex (VOR) of individuals over 60 years of age who have not been diagnosed with a specific vestibular pathology.

Methods: Bilateral six-semicircular canal video head impulse test (vHIT), Dizziness Handicap Inventory and European Evaluation of Vertigo scales were applied to participants.

Results: In total, 103 participants were included in the study (75 male, 28 female), and the mean age was 69.35 ± 7.41 years. The mean age of 7th decade group was 64.32±3.12 (59 participants; 38 male, 21 female), and the mean age of 8th decade and older group was 76.11±5.93 (44 participants; 37 male, 7 female). No significant differences were found between the VOR gains of the lateral or vertical semicircular canals between the 7th decade and 8th decade and older groups ($p>0.05$). In the 8th decade and older group, the presence of right lateral semicircular canal corrective saccade and left posterior semicircular canal corrective saccade showed a positively moderate correlation with VOR gains of the same semicircular canals ($r=0.455$, $p=0.002$, and $r=0.518$, $p=0.001$, respectively). No significant correlation was found between age and VOR gain in the 7th decade group, however, there was a negatively weak correlation between age and left lateral semicircular canal VOR gain ($r=-0.366$, $p=0.017$) in the 8th decade and older group.

Conclusion: While assessing the age-related changes in VOR using vHIT, it must be considered that the changes related to aging of the vestibular system begin to emerge in the population over 70 years of age, and corrective saccade findings may be more informative than VOR gains in revealing these changes.

Keywords: Aging, corrective saccades, vestibulo-ocular reflex, video head impulse test

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The vestibulo-ocular reflex (VOR) provides a stable and clear view of the environment during angular or linear movements of the head. It is characterized by the formation of eye movement at the same velocity and in the opposite direction to the head movement. VOR gain is defined as the velocity of the eye movement divided by the velocity of the head movement.[1,2] Among the quantitative evaluation methods of VOR, the video head impulse test (vHIT) is a practical, fast, and reliable method which evaluates angular VOR.[3-5] In VOR deficiencies, to maintain the fixation on a target while head movements the corrective saccadic eye movements are used as a compensatory oculomotor movement.[1,6,7]

Primary factors affecting vHIT results may include increased patient anxiety/arousal levels, velocities and directions of head impulses, goggle tightening, distance of the target,

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hand placement, location of the camera, and age of patient.[1,2,5,8,9] The high number of factors affecting the vHIT test causes to continue the studies to determine the age-specific values of the vHIT normative data, unlike the caloric or rotation chair tests that evaluate the VOR. In addition, determining the relationship between vestibular complaints due to aging and the VOR are important parameters in revealing aging-related changes in the vestibular system. The aims of this study are to analyze the six-semicircular canal (SCC) vHIT findings and to contribute to the literature by comparing these findings according to the demographic characteristics, history of chronic disease, and presence of subjective vertigo complaints in the participants over 60 years of age, without specific vestibular pathology.

Subjects and Methods

A total of 103 participants over the age of 60 who can move independently were included in this study, which was conducted in a municipal facility. This municipal facility was preferred in this research because the number of elderly people visiting the facility was sufficient to evaluate more than 100 individuals over the age of 60 and the physical conditions of the building were suitable for vestibular assessment. The power analysis of the study was calculated using the G*Power 3.1.9.4 program.[10] It was determined that the study, conducted with 103 participants, had an effect size of 0.6, an alpha value of 0.05, a critical t-value of 1.66, and a power of 91% at 101 degrees of freedom. Ethical approval of the study was obtained from the local ethics committee (Istanbul Medeniyet university Goztepe Training and Research Hospital Local Ethics Committee, No. 2022/0435; Date: 06/07/2022). Written informed consent was obtained from each subject. First, participants were examined by an otorhinolaryngologist. The age, gender, history of chronic diseases, and presence of subjective vertigo/imbalance complaints were also recorded using a participant information form. Participants who were diagnosed before with vestibular, neurological or cervical pathology, and could not cooperate with the vHIT were excluded from the study.

In addition to the information form, to measure the subjective vertigo complaints of the participants, the European Evaluation of Vertigo Scale (EEV)[11] and Dizziness Handicap Inventory (DHI)[12] were applied as individual interviews. EEV is a 5-question questionnaire in which vestibular symptoms are scored by the patient, and each question is scored from 0-4. The total score can range from 0 to 20, and an increase in the total score indicates a worsening of vestibular symptoms.[11] DHI is a scale that evaluates how a person's quality of life is affected by vestibular symptoms. It consists of physical (7 questions), emotional (9 questions) and functional (9 questions) sub-categories and a total of 25 questions. Each question is scored as 0=never, 2=sometimes or 4=always, the total score can be between 0-100. Higher scores represent the increasing handicap due to vestibular symptoms. The handicap is mild if the total score is below 30, moderate if it is between 31-60, and severe if it is between 61-100. For emotional and functional subscores, 0-12 indicates mild, 13-24 indicates moderate and 25-36 indicates severe handicap. For the physical subscore, 0-9 points indicate mild, 10-18 points moderate, and 19-28 points severely handicapped.[12]

For the vHIT, EyeSeeCam video-oculography system (EyeSeeCam, Munich, Germany) was used. For all participants, the camera of the device was on the left side. During the test, the participants sat facing a wall at a distance of 1.5 meters, sitting upright in a chair that had no wheels. The vHIT goggles were placed tightly. After the head and eye calibrations 10 to 15 head impulses were applied in each of the lateral and vertical SCCs until at least seven sufficient responses are recorded.[13] After the test, responses with artifacts were removed from the screen. The maneuvers were performed by an experienced audiologist (BM) to rule out differences between examiners.[14] The clinician's hands were placed on the chin without touching the goggle or headband during the horizontal SCC maneuvers. In the test of the left anterior–right posterior vertical SCCs, the right hand was placed under the chin and the left on top of the head. In the test of the right anterior–left posterior vertical SCCs, the right hand was placed on top of the head and the left under the chin. During the maneuvers, the patients were asked to keep their necks completely relaxed and look at the wall sticker. The clinician stood behind the patient's right or left shoulder, following the plane of the vertical SCCs tested. The head impulse velocities were kept in the range of 150° to 300° per second for each SCC. The VOR gains obtained by the excitation of each SCC were measured by keeping the head angle in the range of 15° to 20° in each plane. Gains of <0.79 for lateral SCCs and of <0.7 for vertical SCCs were considered pathological.[14] Saccades occurring in the same direction as the VOR in each SCC, with similar latency and amplitude at least twice, and occurring between 25-503 milliseconds, were recorded as corrective saccades.[15,16]

Statistical Analysis

Participants were divided into two age groups "7th decade" (60-69 years old), and "8th decade and older" (70-92 years old). The continuous data's means and standard deviations and the categorical data percentages were calculated. The distribution of data was not normal thus non-parametric methods were used for statistical analysis. The chi-square test was used for the comparison of the categoric data, and the Mann-Whitney U test was used for the comparison of continuous data to analyze the significance of the difference between two independent groups. The significance of the difference between the VOR gains of the right and left SCCs was evaluated with the Wilcoxon test. Spearman's correlation coefficients were used to evaluate the relationships of VOR gains and corrective saccade presence with other parameters. The statistical analyses were performed using SPSS version 22.0 (IBM, USA). Statistical significance was accepted as $p<0.05$.

Results

In total, 75 (72.8%) of the participants were male and 28 (27.2%) were female, and the mean age was 69.35±7.41 years. It was determined that the mean age of 59 participants (38 male, 21 female) in the 7th decade group was 64.32±3.12, and the mean age of 44 (37 male, 7 female) participants in the 8th decade and older group was 76.11±5.93 years. The presence of subjective vertigo complaints ($p=0.049$) and right anterior SCC corrective saccades ($p=0.012$) and total presence of corrective saccades were significantly higher in the 8th decade and over group ($p=0.000$) than 7th decade group (Table 1). In addition, it was determined that EEV and DHI total scores were higher in the 8th decade and older group ($p=0.012$ and $p=0.013$, respectively), also it was consistent with mild involvement in both groups. On the other hand, no significant differences were found between the VOR gains of the lateral or vertical SCCs between the 7th decade and 8th decade and older groups (Table 1).

When the right and left side VOR gains of all participants were compared with each other, VOR gains of left lateral SCC slope ($p=0.002$), left lateral SCC 60 ms ($p=0.001$), left anterior ($p=0.000$) and right posterior SCCs ($p=0.000$) were significantly higher than their opposites (left>right). When these analyzes were performed separately for age groups, left lateral SCC slope gains ($p=0.001$), left lateral SCC 60 ms gains ($p=0.000$), left anterior SCC ($p=0.000$) and right posterior SCC gains ($p=0.000$) were significantly higher in the 7th decade group compared to their opposites (also left>right). However, in the 8th decade and older group, the left VOR gain superiority was only valid for the left anterior SCC ($p=0.000$) and right posterior SCC VOR gains ($p=0.000$) (Table 2).

Both the 7th decade, and 8th decade and older group's, ateral and vertical SCC VOR gains did not differ significantly between genders, between those with and without a history of chronic disease, and between those with and without subjective vertigo complaints (Tablo 3). EEV and DHI scores of participants with subjective vertigo complaints were significantly higher in both groups (Table 3).

The p values of the comparison of SCC-specific corrective saccades presence with other parameters were presented in Table 4. According to the comparison, we determined that neither in the 7th decade group nor in the 8th decade and older group, gender, presence of chronic disease history or presence of subjective vertigo complaints did not affect the presence of lateral or vertical SCC corrective saccades.

The correlation coefficients between the corrective saccade presence and VOR gain were also calculated. No significant relationships were found in the 7th decade group. However, the presence of right lateral SCC corrective saccades showed a positively moderate correlation with right laterall SCC slope gains ($r=0.455$, $p=0.002$) and right lateral SCC 60ms gain ($r=0.459$, $p=0.002$) in the 8th decade and older group. Similarly, a positive moderate correlation ($r=0.518$, $p=0.001$) was found between left posterior SCC gain and left posterior SCC corrective saccade presence. These findings indicated that in the 8th decade and older group, the VOR gains decreased as the corrective saccade presences increased.

When the relationship between age and VOR gain was analyzed, no significant correlation was found between age and VOR gain in the 7th decade group. There was a negatively weak correlation between age and left lateral SCC slope gain ($r=-.366$, $p=0.017$) and left lateral SCC 60 ms gain ($r=-.48$, $p=0.001$) in the 8th decade and older group. In both groups, EEV and DHI scores were strongly correlated with each other ($r=0.851$, $p=0.000$) and with the presence of subjective vertigo complaints ($r=-0.941$, $p=0.000$ and $r=-0.781$, $p=0.000$, respectively) but not with any correlation with the findings of vHIT (neither VOR gains nor presences of corrective saccades) ($p>0.005$).

Discussion

Histopathological studies have reported that there is a 6% decrease in the number of vestibular hair cells per decade after birth, primary vestibular afferent fibers begin to degenerate from middle age, and only 35% of these fibers are preserved between 70-85 years of age. The neurons of the vestibular nuclei decrease by 3% per decade between the ages of 40-90. Similarly, the cells in the Scarpa's ganglion decrease after the age of 30, and this decrease accelerates after the age of 60.[8,17,18,19,20] It has been determined that the rate of dizziness and vertigo is 30% in the population over 60 years of age.[18,21] The fact that histological changes in peripheral and central vestibular structures become evident around middle age, and that these changes increase

Table 1. Demographics, subjective scores and video head impulse test findings of the participants according to the age groups.

Demographics	**(n,%)**			
	All participants n=103	**7th decade n=59**	**8th decade and over n=44**	**chi-square p**
Gender				
Males	75, 72.8	38, 64.4	37, 84.1	0.043
Females	28, 27.2	21, 35.6	7, 15.9	
History of chronic diseases				
Yes	64, 62.1	36, 61	28, 63.6	0.839
No	39, 37.9	23, 39	16, 36.4	
Hypertension	13, 12.6	7, 11.9	6, 13.6	
Diabetes mellitus	5, 4.9	4, 6.8	1, 2.3	
Hypertension+ diabetes mellitus	10, 9.7	7, 11.9	3, 6.8	
Other	36, 36	18, 37.2	18, 40.8	
Presence of subjective vertigo complaints				
Yes				
No	29, 28.2	12, 20.3	17, 38.6	0.049
Vertigo	74, 71.8	47, 79.7	27, 61.4	
Imbalance	17, 16.5	5, 8.5	12, 27.3	
Vertigo+imbalance	7, 6.8	5, 8.5	2, 4.5	
Presences of corrective saccades	5, 4.9	2, 3.4	3, 6.8	
Right lateral semicircular canal	8, 7.8	4, 6.8	4, 9.1	0.721
Left lateral semicircular canal	4, 3.9	1, 1.7	3, 6.8	0.31
Right anterior semicircular canal	5, 4.9	-	5, 11.4	0.012
Left posterior semicircular canal	9, 8.7	3, 5.1	6, 13.6	0.166
Left anterior semicircular canal	1, 1	-	1, 2.3	0.427
Right posterior semicircular canal	6, 5.8	3, 5.1	3, 6.8	1
All canals		11, 18.7	22, 50.8	0.000
		Mean±SD	**p**	
Age	69.35±7.41	64.32±3.12	76.11±5.93	0.000
European Evaluation of Vertigo Scale				
Total score	1.61±3.26	0.83±2.25	2.65±4.06	0.012
Dizziness Handicap Inventory				
Physical subscore	2.05±4.9	1.38±4.11	2.95±5.73	0.033
Emotional subscore	0.81±2.75	0.71±2.98	0.95±2.42	0.097
Functional subscore	1.96±5.23	1.35±4.71	2.77±5.81	0.007
Total score	4.83±12.25	3.45±11.29	6.68±13.33	0.013
Vestibulo-ocular reflex gains				
Right lateral canal slope gain	1.04±0.21	1.05±0.22	1.02±0.21	0.457
Left lateral canal slope gain	1.09±0.21	1.12±0.22	1.04±0.18	0.115
Right lateral canal 60 ms gain	0.97±0.24	0.97±0.24	0.97±0.24	0.953
Left lateral canal 60 ms gain	1.05±0.25	1.08±0.26	0.99±0.24	0.093
Right anterior vertical canal slope gain	1.07±0.3	1.08±0.29	1.04±0.32	0.574
Left posterior vertical canal slope gain	0.97±0.32	1.01±0.29	0.91±0.35	0.071
Left anterior vertical canal slope gain	1.34±0.31	1.33±0.31	1.35±0.31	0.677
Right posterior vertical canal slope gain	1.24±0.27	1.22±0.27	1.27±0.26	0.524

after the age of 60, and the complaints of dizziness and vertigo increase, led to investigation of whether there are age-related changes in the VOR in literature.

In the literature, since 2015, it has been seen studies evaluating the age-related changes of the high-frequency VOR in healthy elders using vHIT. Li et al.,[19] reported that VOR

Table 2. Differences of vestibulo-ocular reflex gains between right and left side

Vestibulo-ocular reflex gains	**All participants n=103 (Wilcoxon test, p value)**	**7th decade n=59 (Wilcoxon test, p value)**	**8th decade and over n=44 (Wilcoxon test, p value)**
Lateral semicircular canals			
Lateral canal slope gains	0.002	0.001	0.308
Lateral canal 60 ms gains	0.001	0.000	0.342
Vertical semicircular canals			
Anterior canal slope gains	0.000	0.000	0.003
Posterior canal slope gains	0.000	0.000	0.000

gains begin to decline after the age of 80 and decrease by 0.002 per year in healthy population. Matino-Soler et al.[9] reported that VOR gain with high velocity head movement (180-200 degree/second) decreases after age 70, and VOR gain with slow velocity head movement (100-120 degree/second) decreases after 90 years of age. McGarvie et al.[17] reported that, the VOR gains were mostly stable until age of 90, but after 80 years old, the posterior SCC VOR gain slightly decreased. Pogson et al.[5] noted that the left anterior and left posterior SCC VOR gains decreased in healthy individuals over 60. Schubert et al.[22] stated that the horizontal VOR gains are not affected by age. Teggi et al.[21] reported that the lateral SCC VOR gains decreased over 80. Trevino-Gonzalez et al.[4] analyzed the lateral SCC VOR gain and gain asymmetry and reported that the VOR findings for healthy individuals up to age 79 were like those of the general adult population. In the population older 79 they obtained a decline at just left lateral SCC VOR gains. Kim et al.[8] reported in their article, which detailed their VOR findings for the lateral and vertical SCCs of 434 healthy individuals without active vestibular complaints, that the horizontal VOR gains decrease over age of 70, and vertical VOR gains decrease over ages of 80, as gradually. Gan et al.[23] reported that VOR gain did not differ between decades, but VOR gains began to decline slightly from age 58 when head velocity was controlled. Mossman et al.[1] evaluated lateral VOR gains, and stated that, the 60ms lateral SCC VOR gains decreased 0.017 with per decade. Jay et al.[7] reported in their research that VOR gains of horizontal SCC decreased with increasing age over age of 58. Yang et al.[6], reported that the lateral SCC VOR gains in healthy individuals aged between 20-69 did not differ according to age. Abakay et al. [24], evaluated six SCCs VOR gain in 129 healthy individuals aged 12-88 years and found that VOR gain did not correlate with age. In our study, we did not find a significant difference between the average of horizontal and vertical SCC VOR gains in the 7th decade group and the 8th decade and older group. When we looked at the correlation coefficients between age and VOR gains, we did not find a significant correlation in the 7th decade group, however, we found a negatively weak correlation between age and slope gains and 60 ms gains of left lateral SCC VOR in the 8th decade and older group.

The general consensus is that the VOR is largely preserved until approximately 75 years of age.[4,8,9,17,19,21] Age-related decrease in the number of vestibular receptor cells and afferent fibrils has been reported histopathologically, but it has been noted that the deficit in VOR gain function is not that obvious. Age-related decrease in the number of vestibular receptor cells and afferent fibrils has been reported histopathologically before, but it has been noted that the deficit in VOR gain function is not that obvious. There are some theories in the literature regarding the preservation of the VOR gain function until old age. It is argued that the protective effect of the cerebellum on the VOR becomes especially evident in activities (magnified vision) or situations (aging) that challenge the VOR function.[17,20,25] Luque et al.,[20] created a cerebellum-dependent neuroanatomical and functional model of VOR adaptation that provides gaze stabilization during head movements. Accordingly, long-term synaptic plasticity realized by the biophysical properties of Purkinje cells of the cerebellum is responsible for the stability of the VOR despite aging. Purkinje cells maintain VOR function despite increasing age by a homeostatic mechanism. The local and global homeostatic compensation of the cerebellum depends on the number of residual fibers in the VOR arch during aging. Another theory is that unlike cochlear efferent neurons, cholinergic vestibular efferent neurons are not affected by age. This can be considered as an important mechanism that ensures the preservation of the VOR at a functional level until older ages.[18] If the VOR gain is preserved until about 80 years of age, we may ask what can be attributed to the vestibular complaints that increase after the age of 60, we encounter the possibility of central influence. It is noteworthy that the number of studies on age-related vestibulo-limbic and vestibulo-

Table 3. The significance of the differences of the vestibulo-ocular reflex gains and subjective vestibular scores according to the test side, gender, presence of chronic disease history, and presence of subjective vertigo complaints.

	Gender (Mann-Whitney U test, p)			**Presence of chronic disease history (Mann-Whitney U test, p)**			**Presence of subjective vertigo complaints (Mann-Whitney U test, p)**		
	All participants n=103	**7th decade n=59**	**8th decade and over n=44**	**All participants n=103**	**7th decade n=59**	**8th decade and over n=44**	**All participants n=103**	**7th decade n=59**	**8th decade and over n=44**
Vestibulo-ocular reflex gains									
Right lateral canal slope gain	0.059	0.36	0.062	0.816	0.968	0.697	0.846	0.234	0.405
Left lateral canal slope gain	0.151	0.538	0.407	0.493	0.089	0.385	0.805	0.129	0.564
Right lateral canal 60 ms gain	0.135	0.348	0.15	0.677	0.525	0.806	0.721	0.282	0.564
Left lateral canal 60 ms gain	0.307	0.84	0.446	0.52	0.053	0.233	0.817	0.059	0.14
Right anterior vertical canal slope gain	0.225	0.179	0.729	0.442	0.703	0.161	0.696	0.572	0.943
Left anterior vertical canal slope gain	0.943	0.77	0.511	0.353	0.907	0.147	0.993	0.09	0.229
Right posterior vertical canal slope gain	0.091	0.284	0.292	0.129	0.292	0.299	0.365	0.913	0.235
Left posterior vertical canal slope gain	0.759	0.358	0.239	0.321	0.838	0.17	0.976	0.704	0.92
Subjective Vestibular Scores									
EEV* total scores	0.769	0.442	0.571	0.788	0.372	0.76	0.000	0.000	0.000
DHI* total scores	0.342	0.099	0.509	0.604	0.426	1	0.000	0.000	0.000

*EEV: European Evaluation of Vertigo Scale; DHI: Dizziness Handicap Inventory.

cortical effects leading to vestibular complaints is increasing.[18]

One of the indicators of VOR function is corrective saccade. In addition to the incidence of corrective saccade, features such as latency, amplitude and peak velocity values can be evaluated with vHIT's up-to-date software. Matino-Soler et al.[9] reported an increased incidence of corrective saccades in healthy individuals over the age of 71. The corrective saccade mean incidence was 16.7% in the group age of until 70, and 66.6% in the group 71 and older, and the VOR gains were significantly lower in those populations with a high incidence of corrective saccades. Yang et al.,[6] stated that incidences of corrective saccades and amplitudes did not change between decades in healthy individuals aged 20-69, and the mean incidence of corrective saccades was around 23% in all decades. Mossmann et al.[1] did not indicate a significant relationship between the incidence of corrective saccades and age. Pogson et al.[5] reported that the corrective saccade amplitude and peak velocity values are affected by the VOR gains. According to their findings, the corrective saccade amplitudes decrease towards the lateral, posterior and anterior SCC, respectively. In healthy individuals over 60 years of age, especially in the lateral SCCs, the corrective saccade amplitudes, incidences, and peak velocities increase. In another study, it was reported that the corrective saccade incidences were not affected by age until the 7th decade, but the incidences and amplitudes of the corrective saccade increased after the 7th decade. In addition, it has been reported that the overt saccades with high amplitudes and early latencies are more common in the elderly with low VOR gains. [16] Jay et al. [7] reported that there is a positively strong correlation between age and the incidence of corrective saccades, and that the incidence and peak velocities of saccades increase with increasing age, but the latencies are stable. In our study, the presence of six SCC corrective saccades were recorded. The total presence of corrective saccades in all SCCs was 18.7% in the 7th decade group, while this value was 50.8% in the 8th decade and older group. In addition, we found that the presence of corrective saccade increased in the SCC with low VOR gain, only in the 8th decade and older group. In our findings, consistent with the literature, it is revealed that the relationship between aging and the presence of corrective saccade is stronger than the relationship between age and VOR gain. Similarly, in the literature, it is stated

Table 4. The significance of the differences between the presence of corrective saccades according to the test side, gender, presence of chronic disease history, and presence of subjective vertigo complaints.

	Gender (Chi-square, p)			History of chronic diseases (Chi-square, p)			Presence of subjective vertigo complaints (Chi-square, p)		
	All participants n=103	7th decade n=59	8th decade and over n=44	All participants n=103	7th decade n=59	8th decade and over n=44	All participants n=103	7th decade n=59	8th decade and over n=44
Presence of corrective saccades									
Right lateral semicircular canal	1	1	0.513	0.253	0.149	1	1	0.572	0.634
Left lateral semicircular canal	0.572	1	1	1	1	1	0.067	1	0.051
Right anterior semicircular canal	0.123	-	0.051	0.154	-	0.141	1	-	0.634
Left posterior semicircular canal	0.701	0.286	1	1	1	1	0.265	0.102	1
Left anterior semicircular canal	1	-	1	1	-	1	1	-	1
Right posterior semicircular canal	1	0.546	0.413	0.671	1	0.543	0.347	0.501	0.549

that the possibility of measuring subclinical age-related vestibular involvement, which cannot be revealed by VOR gain information, by analyzing the characteristics of the corrective saccades, will provide stronger evidence.[7,16]

Although the participants consisted of individuals without vestibular diseases, the difference in the VOR gains between right and left side in the literature is remarkable. Most of the studies[4,6,7,8,9,17,23] reported that the VOR gains were higher in the right head impulse than in the left. The vHIT camera recorded the right eye in all studies where the right VOR gains were higher than the left. While recording from the right eye, in order to maintain the fixation to the target, the right eye adducts with the right head impulses, and the right eye abducts with the left head impulses. It has been reported in the bilateral eye recording scleral coil test that the adductor oculomotor muscles are 15% stronger than the abductor muscles.[17,26] In our study, the camera recorded from the left eye, the left lateral SCC slope and left lateral 60 ms gains, left anterior SCC and right posterior SCC gains were significantly higher in all participants compared to their opposites. This finding supports the finding of higher VOR gains in head impulses causing adduction of the eye.

When VOR gains were compared by gender, some studies indicated that there was no difference between males and females[1,7,9,17,24], and some studies indicated that it was higher in males.[4,21,22,27] The authors explained the low lateral SCC VOR gain in women as being affected by hormonal structure and menopausal process.[21,22,27] Jay et al.[7] reported that the incidence of corrective saccades and peak velocity values were slightly but significantly higher in males than in females. They did not explain this finding with any justification. Although there were more male participants in our study, neither VOR gains, nor corrective saccade presences differed. These findings are in line with studies stating that there is no difference according to gender.

Agrawal et al.[25] stated that the prevalence of balance dysfunction is higher in the elderly population with cardiovascular risk factors such as hypertension, diabetes, and smoking 20 packs of cigarettes per year, but they did not apply vHIT in that study. The common conclusion in studies evaluating vHIT is that cardiovascular diseases such as hypertension and diabetes do not affect VOR gains in the elderly population without vestibular disease.[21,19] Li et al.[19] recorded the history of hypertension, diabetes mellitus and hyperlipidemia in 109 healthy participants aged 26-92 years, and named the presence of these diseases as the 'Cardiovascular Risk'. In their study, no significant relationship was found between Cardiovascular Risk and VOR gains. Similarly, Teggi et al.[21] evaluated VOR gains in 58 participants aged 70-96 years, and recorded the history of central nervous system vascular diseases and cardiovascular disease. In that study, history of cardiovascular disease did not present a significant relationship with VOR gains, however, presence of central nervous system vascular diseases affected VOR gains negatively. In our study, it was found that the presence of hypertension, diabetes mellitus, or both did not affect the presence of corrective saccades or VOR gains in both 7th decade group and 8th decade and older group. This finding supports the other studies.

In this study, elderly individuals who were not diagnosed with a vestibular disease and who move independently were included. In this population, where all the participants were 60 years or older, subjective vertigo complaints were questioned in order not to neglect age-related subclinical vestibular complaints, and additionally subjective vestibular questionnaires were applied. In addition to the fact that VOR gains in the elderly do not show a strong correlation with age-related histological or functional involvement of the vestibular system[15,17,21,18], no study has been found to evaluate the relationship between age-related subjective vertigo complaints or vestibular questionnaires and vHIT findings in literature. In terms of methodological similarity, McCaslin et al.[28] did not find a significant relationship between DHI scores and VOR gains in adult vestibular neuronitis patients, although the patients had active vestibular complaints. In contrast, Li et al.[29] evaluated the relationship between DHI scores and vHIT findings in adult vestibular neuronitis patients and found a negative moderate correlation between vertical and lateral VOR gains and DHI scores, however, they did not detect any relationship between gain asymmetries and DHI scores in any of the SCCs. They found a positively strong correlation between the incidences of lateral SCC correcting saccade, and a positively moderate correlation between the incidences of vertical SCC correcting saccade and DHI scores. This finding may support the finding that corrective saccades are stronger parameters in reflecting vestibular influence than VOR gains. There was only one study in which the EEV questionnaire was applied together with vHIT, which was conducted in Covid (+) patients with vestibular complaints.[30] The mean EEV score was found to be 4.5 out of 20 in these patients and significantly higher than in healthy controls. They reported significant reductions in VOR gains compared to healthy individuals but unfortunately did not analyze the relationship between EEV scores and VOR gains.[30] In our study, the presence of subjective vertigo complaints, DHI, and EEV scores were significantly higher in the 8th decade and older group compared to the 7th decade group. On the other hand, we found that neither the VOR gains nor the presence of corrective saccades in all SCCs was affected by the presence of subjective vertigo complaints, DHI or EEV scores in both groups. Since our participants consisted of individuals who were not diagnosed with vestibular disease, DHI and EEV scores were consistent with slight involvement in both groups and the lack of correlation with vHIT findings was thought to be related to this. The lack of a relationship between subjective vertigo complaints and vHIT findings may support the fact that the participants with no diagnosed with vestibular disease.

Developments in technology and enhancement of the knowledge about vestibular physiology cause new diagnostic test techniques to be added to vestibular evaluation protocol. The increment in vestibular complaints with aging makes it very important to identify findings specific to the elderly population for each vestibular test. When interpreting vHIT findings in elderly patients presenting with vestibular complaints, the side of the camera and whether the patient is over 80 years of age should be taken into consideration.

Our study has some limitations. The first is that the elderly people included in the study show a distribution that is unsuitable to be analyzed by dividing their ages into decades (i.e., because the patients in their 60s and 70s formed the majority). The second is a relatively small number of participants included in the study. The third limitation is that videonystagmography, caloric test, bedside tests or vestibular-evoked myogenic potential tests could not be applied to the participants, as this study was conducted in a nonclinical condition. The fourth limitation is that the latency, amplitude and peak velocity analyzes of the corrective saccades of this population could not be performed.

Conclusion

The vHIT is a test that can be safely applied among the elderly population by an experienced clinician, and it allows for evaluation of the VOR findings of the horizontal and vertical SCCs. Left ateral SCC VOR gains decrease as age increases in the population of 8th decade and older. In the elderly, over 60 years of age without a diagnosis of vestibular disease, the gender, history of hypertension or diabetes mellitus affecting the cardiovascular system, and the presence of subjective vertigo complaints do not affect the VOR gains or presence of corrective saccades. It can be said that the difference between the right and left VOR gains is related to the head impulse in the same direction as the camera location. In the 8th decade and older group, as the corrective saccade presence increases, the VOR gains decrease, however, this finding is not valid for the group of 7th decade. While assessing the age-related changes in VOR using vHIT, it must be considered that the findings related to aging of the vestibular system begin to emerge in the population over 70 years of age, and corrective saccade findings may be more consistent and informative than VOR gain in revealing these changes.

Disclosures

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