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Evaluation of the vestibulo-ocular reflex with the functional head impulse test in people with motion sickness

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Abstract

Background In this study, we aimed to examine functional VOR values with and without optokinetic background stimulation in fHIT (functional head impulse test) in individuals with motion sickness.

Methods Forty-two individuals between the ages of 18–50 years were included in study. The lateral fHIT test was applied to the motion sickness group and the control group with and without dynamic optokinetic (OKN) background stimulation.

Results In the control group, no significant difference was observed in the correct response percentages (% CA) for fHIT and OKN-fHIT for the right and left lateral canals ($p > 0.05$). In the MS group, a significant difference was observed when comparing fHIT and OKN-fHIT correct response percentages for the right and left lateral canals ($p < 0.05$).

Conclusions It has been observed that the optokinetic background triggers the disease in individuals with MS, and there is a decrease in the percentage of correct readings in the fHIT.

Keywords Motion sickness, Functional head ımpulse test, *Vestibulookuler refleks*

Background

Motion sickness (MS) refers to the autonomic response of the moving environment and other signs and symptoms such as nausea, vomiting, pallor, and cold sweats caused by stimuli [1]. Although the etiology of MS is not fully known, there are various theories. The sensory conflict theory is the most widely accepted theory and proposes that MS results from an intersensory dissonance involving conflicting vestibular, visual, and somatosensory stimuli [2, 3]. Although MS usually occurs with vestibular stimulation, it can also occur with visual stimulation (for example, prolonged optokinetic stimulation) [4]. Studies have shown that MS can occur in individuals exposed to provocative physical movements, impaired vestibulo-ocular reflexes (VOR), or exposed to optokinetic stimulation [5].

MS can be caused by a wide variety of situations, including boats, cars, airplanes, amusement park rides, weightlessness in space, simulators, and virtual reality. The term "road sickness" includes sea sickness, car sickness, air sickness, and space sickness [6]. The increased use of new visual technologies such as virtual reality and driverless autonomous vehicles may increase public exposure to environments that can cause MS [7, 8]. MS has become a common problem, as passive motion (car, bus, train, and plane) and the illusion of passive motion

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(video games, 3D movies, and virtual reality on big screens) are now common problem in modern life [9].

The vestibular system and visual system complement each other as they elicit slow-phase eye movements to stabilize images on the retina. Optokinetic-pursuit eye movements occur with visual movements, while VOR occurs with head movements. These two systems work in harmony with each other [8]. Functional head impulse test (fHIT) is a new test used through gyroscope and a software. fHIT provides evaluation of functional VOR [10]. It is a quick and easy diagnostic tool in the diagnosis of vestibular pathologies (bilateral or unilateral vestibular losses, etc.) that provides information about the ability to read an optotype (Landolt C) that is randomly and briefly displayed on the screen during passive head movement [11]. The sensor fixed to the patient's head measures the acceleration of the patient's head. fHIT measures the recognition percentage by marking the Landolt C optotype briefly displayed on the computer screen. Landolt C optotype is one of the eight possible orientations used in the fHIT test. A keyboard containing the orientations of the optotype is given to mark the optotype seen on the screen during head movements. The aim of our study is to determine the functional VOR effect in the MS group in the presence of optokinetic stimuli by applying fHIT in the horizontal plane in with and without optokinetic stimulation to MS patients and control group.

Methods

The study data was collected between March and December 2022 at Ankara University, Department of Otorhinolaryngology, Audiology, Balance and Speech Pathology Unit. All participants signed the informed consent form, and the principles of the Declaration of Helsinki were followed throughout the study (Human Research Ethics Committee, Faculty of Medicine, Ankara University, date: 10.02.2022 and no: İ03 106-22).

Participants

A total of 42 individuals between the ages of 18 and 50 years were included in the study. Twenty-one people with a mean age of 30.09 ± 6.91 years were included in the control group, and 21 people with a mean age of 31.04 ± 5.74 years were included in the MS group. A pure-tone audiometry test with clinical audiometer (AC-40, Interacoustics, Denmark) and immitansmetric (GSI Tympstar, USA) examination were performed on all individuals participating in the study. Those with a pure-tone average of 25 dB and better at frequencies of 500 Hz and 4000 Hz and those with type A tympanogram according to the Jerger classification were included in the study. VNG (videonystagmography) test was performed for each individual in the control group and MS group. Individuals with normal oculomotor test results, no nystagmus observed in positional tests, and normal head shake test results were included in the study. Those with diagnosed neurological and otological diseases, neck problems, and vestibular migrain, those who use vestibular suppressants, and those who did not volunteer to participate in the study were not included in the study.

Vestibular history was taken from all individuals. The Barany Society's motion sickness diagnostic criteria were used for diagnosing MS, and the Motion Sickness Susceptibility Questionnaire Short-Form (MSSQ-SF) questionnaire, the validity and reliability of which was made by Uğur E. in Turkish, was used, and those with a score of 80% and above were included in the MS group, while those without complaints of motion sickness and those with normal results were included in the control group.

Functional head impulse test

Individuals were seated at a distance of 1.5 m from the computer screen, a gyroscope measuring head acceleration during head movements was fixed on the head (forehead) of the individuals, and their hands were given a keyboard to mark the optotype they saw on the screen. Before fHIT, the static visual acuity of the individuals was determined. Individuals were asked to mark the optotype they saw on the screen from the keyboard without doing a head movement. Static visual acuity was determined by decreasing the size of the optotype after correct answers. The size of the optotype in the fHIT test is determined by the system by magnifying the static visual acuity by 0.6 logMAR.

In the fHIT (Beon Solutions, Zero Branco, Italy), the head of the individuals was moved to the right and left in a random horizontal plane with a 15–20° angle, and the patient was asked to mark the optotype he saw on the screen. Head-thrusting movements were used in random order. At this point, in the acceleration range of 4000–5000–6000°/s^2, sudden small thrust movements of the head, not exceeding 10–20 in the lateral plane, were applied. Evaluation in the plane of the lateral canal was also analyzed by taking the average of the % CA (correct answer) ratios between 4000 and 6000°/s^2. In each patient, 15 impulses were taken to the right and to the left. The test was applied to all individuals first without background optokinetic stimülation and then with optokinetic stimulation (OKN-fHIT) in the background. Between the two stages, the patients rested for 5 min. The lateral fHIT test result of a participant from the control group is shown in Fig. 1, and the optokinetic stimulation image and keyboard are shown in Fig. 2.

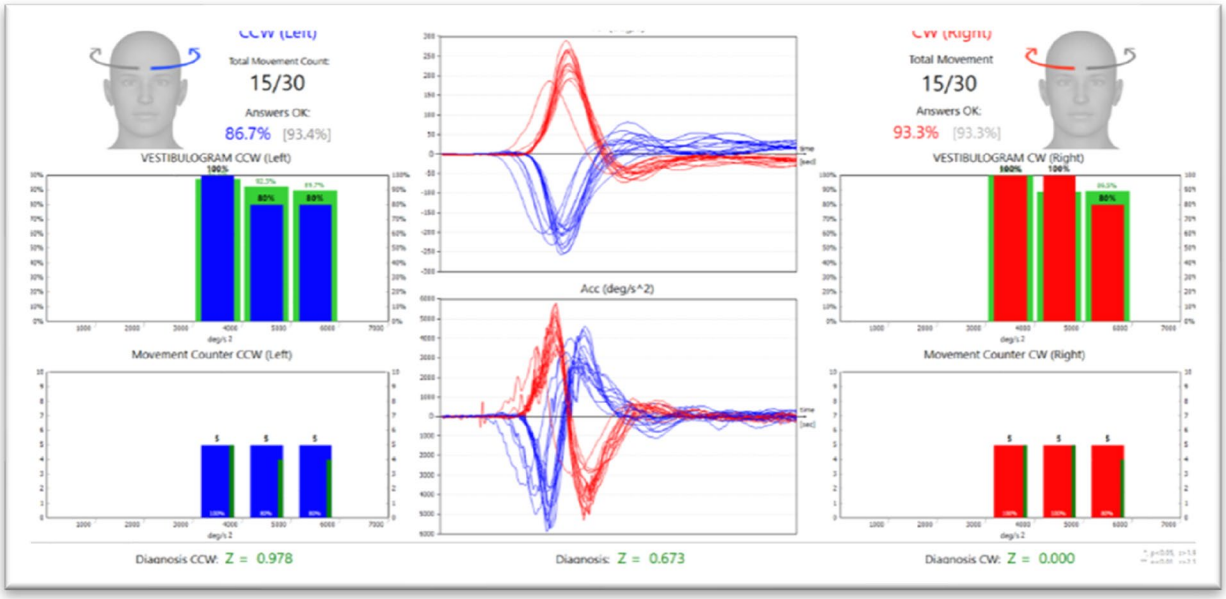

Fig. 1 Lateral SCC fHIT results of a participant from the control group

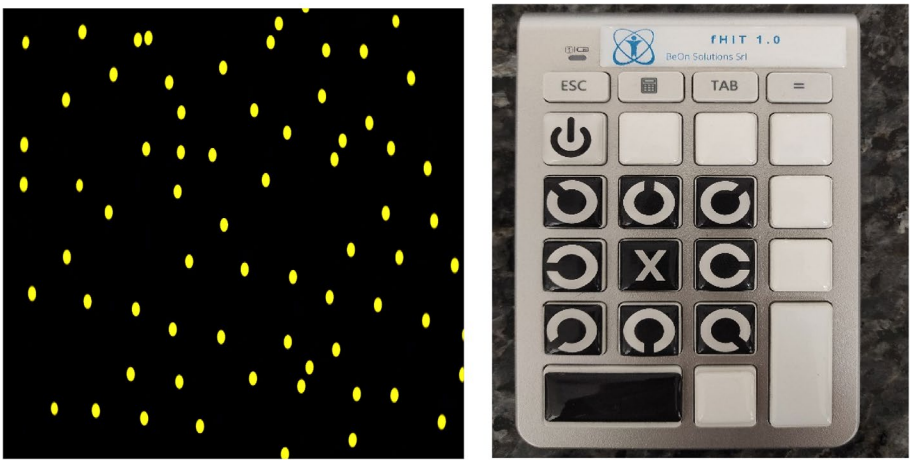

Fig. 2 Image of optokinetic stimulation and keyboard in fHIT test

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 21.0 software (IBM Corp.; Armonk, NY, USA). The descriptive data were presented with mean and standard deviation for age and continuous variables and frequency and percentage for gender and categorical variables. Pearson chi-square test was used for control and study groups comparison regarding gender variable. The continuous variables were normally distributed or not were evaluated with the Shapiro-Wilk test.

While performing the statistical analysis, it was evaluated with the histogram curves whether the data was normally distributed or not. Paired samples *T*-test was used to normal distributed data when comparing fHIT and OKN-fHIT. After evaluating and calculating the numerical difference MS group and control group, Student's *t*-test or Mann-Whitney *U*-test was used in two-group comparisons. $p < 0.05$ was considered statistically significant.

Table 1 Comparison of fHIT and OKN-fHIT results within group Grafic

		fHIT % CA (mean ± SD)	OKN-fHIT % CA (mean ± SD)	*p*-value
Control group	Right lateral SCC Fhıt % CA	93.39 ± 8.63	91.41 ± 7.75	0.23
	Left lateral SCC Fhıt % CA	90.62 ± 6.73	88.33 ± 7.17	0.074
MS group	Right lateral SCC Fhıt % CA	88.75 ± 7.83	82.26 ± 9.85	**0.012***
	Left lateral SCC Fhıt % CA	85.30 ± 9.33	79.14 ± 7.59	**0.006***

* $p < 0.05$. *% CA*, correct answer percentage

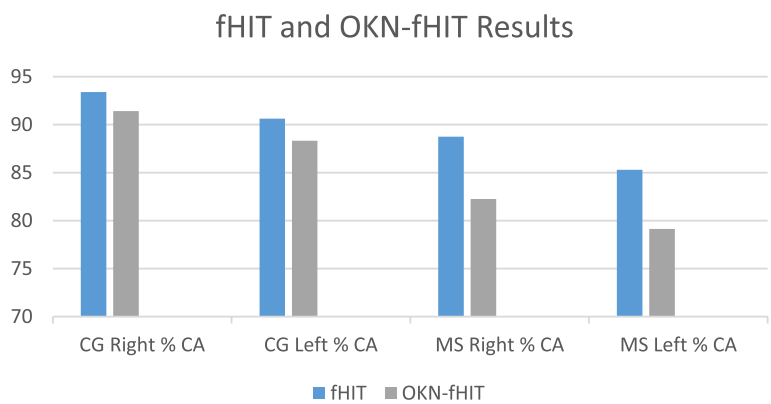

Fig.3 Right and left lateral channel fHIT and OKN-fHIT results of control and motion sickness groups

Results

The control group was consisted of 21 participants, and the MS group was consisted of 21 participants. The mean age of the control group was 30.09 ± 6.91, and the mean age of the MS group was 31.04 ± 5.74 years. There was no statistically significant difference between the control and MS group ($p > 0.05$).

fHIT and OKN-fHIT averages for the right and left lateral canals of the control group and MS group are given in Table 1 and Fig. 3. The fHIT and OKN-fHIT results were compared for the right and left lateral canals within the group. In the control group, no significant difference was observed in the percentages of correct answers (% CA) for fHIT and OKN-fHIT for the right and left lateral canals ($p > 0.05$). In the MS group, a significant difference was observed when comparing fHIT and OKN-fHIT correct response percentages for the right and left lateral canals ($p < 0.05$).

The fHIT and OKN-fHIT results obtained for the right and left ear lateral canal of the control group and MS group of the study were compared between the groups (Table 2).

In the study, right lateral canal (*p*: 0.040) and left lateral canal (*p*: 0.019) fHIT correct reading percentages of the control group and MS group, and right lateral canal (*p*: 0.001) and left lateral canal (*p*: 0.001) OKN-fHIT correct reading significant difference, was observed between the percentages. In the presence and absence of optokinetic stimulus, fHIT correct reading percentages were higher in the control group than in the MS group.

Table 2 Comparison of fHIT and OKN-fHIT results between groups

Ear side		Control group Mean ± SD	MS group Mean ± SD	*p*-value
Right lateral SCC	fHIT % CA	93.39 ± 8.63	88.75 ± 7.83	**0.040***
Right lateral SCC	OKN-fHIT % CA	91.41 ± 7.75	82.26 ± 9.85	**0.001***
Left lateral SCC	fHIT % CA	90.62 ± 6.73	85.30 ± 9.33	**0.019***
Left lateral SCC	OKN-fHIT % CA	88.33 ± 7.17	79.14 ± 7.59	**0.001***

* $p < 0.05$. *% CA*, correct answer percentage

Discussion

MS is a very common phenomenon, and almost everyone has experienced MS at least once in their life [12]. Illusions of motion caused by the moving visual environment can cause MS, and today, with the increase in vehicle use and the increase in screen exposure, the incidence of MS has increased [9, 13]. Visual and vestibular factors play a role in the development of MS. MS patients have

reported dizziness and various symptoms in environments with moving backgrounds. This situation in MS patients has been reported as visual field dependence [14].

Recently, the fHIT, which measures the percentage of correct recognition of the optotype appearing on the screen during passive head movements with different accelerations, has been developed to evaluate the functional performance of the vestibulo-ocular reflex [15]. When the fHIT test is combined with optokinetic stimulation, it can detect impaired integration between visual and vestibular stimuli [16].

In our study, we evaluated the effect of a moving visual field on functional VOR in MS patients with the fHIT. With optokinetic background stimulation in the control group and MS group, a decrease in the percentages of lateral canal VOR was observed, but this decrease was not found to be significant in the control group ($p > 0.05$). In the MS group, in the presence of optokinetic stimuli, the percentages of correct reading of the right and left lateral VOR showed a statistically significant decrease. The absence of a significant difference between fHIT and OKN-fHIT in the normal group showed that visual illusion did not impair VOR functionality in normal individuals, but the moving visual field could affect VOR in MS individuals. These results showed that there may be impairments in visual-vestibular input integration in individuals with MS.

Kumar et al. evaluated VOR in MS and control groups using head impulse test paradigm (HIMP) and suppressive head impulse test paradigm (SHIMP) tests. Saccades were not observed in the HIMP test in both groups, and anticompensatory saccades were observed in the SHIMP test. No significant difference was observed between groups with and without MS in terms of VOR gain and asymmetry [17]. In another study, cVEMP and vHIT tests were applied to the MS and control group. In this study, no significant difference was observed between the two groups in the lateral canal VOR gain values [18].

In our study, the percentages of correct readings obtained in the MS group were observed as normal in the right and left lateral fHIT performed without optokinetic stimuli. However, the correct reading percentages were significantly higher in the control group than in the MS group. This shows that there is no decrease in VOR gains in MS patients but a decrease in the functional evaluation of VOR compared to normal subjects.

We thought that by using optokinetic stimulation in fHIT test application, by triggering MS in patients, visual acuity would decrease, and correct reading percentages would decrease. While no significant difference was observed between the right and left lateral fHIT and OKN-fHIT results in the control group of our study, a significant decrease was observed in the right and left lateral correct reading percentages in the MS group in the presence of optokinetic stimuli. This situation suggested that optokinetic stimulation triggered MS in the MS group.

In the fHIT performed in the horizontal plane in the presence and absence of optokinetic stimulation in patients with vestibular migraine, the percentage of correct reading was found to be 92.07% without optokinetic stimulation and 73.66% with optokinetic stimulation [19]. As a result of the study, fHIT was recommended to be used in clinical practice in individuals with vestibular migraine. In our study, when the intergroup fHIT and OKN-fHIT results were compared, the results in the MS group were found to be significantly lower ($p < 0.05$). In the MS group, a decrease in the percentage of correct reading was observed with optokinetic stimulation, similar to those with vestibular migraine. For this reason, it was thought that it would be useful to use the fHIT test in clinical practice in individuals with MS.

Conclusion

It has been observed that the optokinetic background triggers the disease in individuals with MS, and there is a decrease in the percentage of correct readings in the fHIT test. These results showed that the fHIT test would be beneficial in clinical practice in individuals with MS. We think that the fHIT test can be used in preparing a vestibular rehabilitation program in individuals with MS and in the follow-up of rehabilitation.

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Authors' contributions
KBB designed the study and collected the data, ZA designed the study and analyzed the data, EO wrote the main document, and STY edited the main text. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study data collected between March and December 2022 at Ankara University, Department of Otorhinolaryngology, Audiology, Balance and Speech Pathology Unit. All participants signed the informed consent form, and the principles of the Declaration of Helsinki were followed throughout the study (Human Research Ethics Committee, Faculty of Medicine, Ankara University, date: 10.02.2022 and no: İ03 106-22). Written consent was obtained from all patients before testing after explaining the aim of the study and the procedure to be done.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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