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Vestibular Evaluation of Children Diagnosed with Specific Learning Disorder

ABSTRACT

Objective: The aim of this study was to determine the vestibular function of children diagnosed with specific learning disorders (SLD).

Methods: This study was conducted with 30 children diagnosed with SLD and 30 healthy children matched for age and sex, and vestibular tests were applied.

Results: Optokinetic and head shake test values in videonystagmography subtests were found to be pathological in the study group, and the lateral asymmetry value in video head impulse test (v-HIT) was found to be significantly higher in the study group. Also, a significant difference was found in the N1 latency, P1-N1 interlatency, P1-N1 amplitude values in the cervical vestibular evoked myogenic potential test, and asymmetry values in the ocular vestibular evoked myogenic potential test.

Conclusion: The current study showed that vestibular functions may differ from normal in SLD patients and that vestibular dysfunction may play a role in symptoms such as postural instability, balance, and gross and fine motor disorders that are frequently observed in these children.

Keywords: Specific learning disorder, head impulse test, nystagmus

Introduction

Specific learning disorder (SLD) is a neurodevelopmental disorder defined as a condition in which academic skills are significantly lower than expected despite age, level of mental development, and education.[1] This disorder leads to impaired functioning in 1 or more areas such as speaking, listening, mathematical skills, reasoning, reading, and writing.[2] In the Fifth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), the prevalence of SLD among children from different cultures and languages, which includes the educational fields of writing, mathematics, and reading, was reported as 4% in adults and 5%-15% in school-age children.[1]

Although there is no clear consensus on the pathophysiology of SLD, the presence of this disorder, which is placed in the class of neurodevelopmental disorders, results from congenital or acquired abnormalities in the function and structure of the brain and is based on a biological basis determined by genetic and environmental factors.[3] Studies conducted in recent years converge with the opinion that SLD occurs due to structural and functional disorders of the central nervous system.[4] The involved region with the most common consensus is the temporal lobe and the planum temporale area (which is a part of this lobe); however, some brain imaging studies have also reported reduction in gray matter volume in both lobules and changes in the cerebellum.[5]

It is known that problems with balance, fine motor skills, and coordination are frequently seen in SLD, as well as retardation in academic skills.[6,7] So this has led researchers to investigate the centers responsible for coordination and balance in the body. In addition to the neuroanatomical changes seen in the cerebellum, according to the previously proposed cerebellar theory of motor skills, impaired cortico-cerebellar pathways have also been associated with

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these motor deficits.[8] On the contrary, some meta-analysis studies examining children with SLD reported no differences in the cerebellum.[9,10] It has also recently been stated that the cerebellum cannot be directly related to the findings in SLD with language and reading disorders.[11] For those reasons, it is thought that there may also be deficits in other areas responsible for balance, fine motor skills, and coordination in SLD.

Another fundamental system responsible for balance is the vestibular system. It plays a role in maintaining balance in basic functions such as gaze stabilization, spatial navigation, and postural orientation.[2] The American Psychiatric Association stated that vestibular hypofunction will be clinically reflected in children as imbalance or falling, especially during high-level motor skills such as walking on a balance beam or jumping.[1]

In the presence of neurodevelopmental or neurological disorders, the prevalence of vestibular disorders may increase further due to the connections of the vestibular system with the central and peripheral nervous systems. Indeed, it has been previously reported that vestibular dysfunction may be associated with a number of problems that may affect motor, behavioral, and cognitive development and tend to overlap with symptoms seen in neurodevelopmental disorders.[12]

It is known that the vestibular system not only takes part in functions such as motor skills and postural stability but also affects cognitive development, educational development, and emotional and social behaviors.[13] However, the literature on whether there is a vestibular dysfunction that may contribute to these balance problems or behavioral characteristics that are common in SLD is scarce. As standard neuropsychiatric examination usually does not include vestibular scanning, it remains unclear whether accompanying vestibular dysfunction is present in those patients that have symptoms such as poor coordination, attention difficulties, and difficulties with reading and writing.

In this study, children diagnosed with SLD were compared with the control group, and it was aimed to investigate whether there is vestibular dysfunction in children diagnosed with SLD.

Material and Methods

Evaluation

This prospective study was conducted on children who were consecutive applicants to our outpatient clinic between 2021 and 2022. About 41 patients who applied with the complaint of learning disability and were diagnosed as SLD according to DSM-5 diagnostic criteria and also 33 age- and sex-matched controls who applied for routine controls to otorhinolaryngology outpatient clinic without academic difficulties were included in this study. Exclusion criteria were receiving any medical treatment, communication disability, chronic disease, previously diagnosed vestibular disease, hearing and vision problems, and the presence of pathology affecting middle ear functions. Exclusion criteria were checked by examining the anamnesis and hospital records of the participants.

Psychiatric evaluations of all participants were made by a child and adolescent psychiatrist, and vestibular evaluations were made by an otorhinolaryngologist and expert audiologists. Clinical interview, detailed history, physical examination, family interview, teacher information notes, and psychometric tests were used to diagnose patients with SLD. Diagnostic evaluations of children in both groups were made with a semi-structured scale of the Schedule for Affective Disorders and Schizophrenia for School-Age Children (6-18 years)-Present and Lifetime Version.[14]

Since 11 patients in the SLD group and 3 patients in the control group had additional psychiatric diagnoses (anxiety disorder, depressive disorder, etc.), these participants were excluded from the study. Informed consent signed by the parents was obtained. Approval for this study was obtained from the Ethics Committee of Inonu University Hospital and from all individuals participating in the study (2021/2335). The study was completed with a total of 60 children, including 30 patients and 30 controls, who agreed to participate in the study and met all criteria.

All children participating in the study completed the sociodemographic data form after a child psychiatrist's evaluation and then were referred to the audiology unit.

Hearing assessment was first performed on all participants by expert audiologists. Video head impulse test (v-HIT), videonystagmography (VNG) test, and cervical and ocular vestibular evoked myogenic potential (c-VEMP/o-VEMP) tests were administered to children with normal pure tone audiometry and speech tests. The data have been recorded.

Measurements

Sociodemographic Data Form: It is a 7-question form that was prepared by the researchers and includes information such as age, gender, presence of chronic disease, middle ear or vestibular disease, and patient contact information.

Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version, DSM-5 November 2016-Turkish Adaptation: The Turkish adaptation of this semi-structured interview schedule, which was updated according to the DSM-5 diagnostic criteria by Kaufman et al,[14] was made by the researchers, and the differences in the translation and back-translation texts and the operability of the interview schedule were evaluated by reviewing the trial interviews with parents and children, and by reviewing the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version, DSM-5 November 2016-Turkish Adaptation, it has taken its final shape. Its validity and reliability were determined by Ünal et al[15] in 2019. This interview was conducted by a child psychiatrist trained in

MAIN POINTS

- *Pathological data were obtained from optokinetic and head shake test results in children with specific learning disorder.*
- *Lateral asymmetry values were obtained in video head impulse test in children with specific learning disorder.*
- *There were significant differences in N1 latency, P1-N1 interlatency, P1-N1 amplitude values in the cervical vestibular evoked myogenic potential test, and asymmetry values in the ocular vestibular evoked myogenic potential test in children with specific learning disorder.*

this field, and the participant was excluded from the study in the presence of additional psychiatric illness.

Videonystagmography Test: One of the most important parameters used in the evaluation of vestibular functions is nystagmus. Videonystagmography is a group test in which the vestibulo-ocular reflex (VOR) is evaluated based on the evaluation and recording of eye movements that occur spontaneously or as a result of visual-vestibular stimuli. The VNG device includes gaze test, pursuit test, saccade test, optokinetic test, positional test, spontaneous nystagmus test, and head shake test. This test was performed with a Micromedical Technologies brand Visual Eyes 4 channel model VNG device. This non-invasive test is also useful to differentiate peripheral or central pathology in the vestibulo-ocular pathway and provides information about the progression and improvement of the pathology.

The child is asked to sit in an upright position by wearing VNG test glasses, and a light bar is placed in front of him, leaving a distance of 1 m. With these glasses, the eye movements of the patient while at rest and during various visual and vestibular stimuli are tracked and recorded in the computer environment; afterwards, the obtained information is analyzed by the computer and the evaluation is completed.

Video Head Impulse Test: It is a new and useful tool used to identify semicircular canal (SCC) dysfunctions. In v-HIT evaluation, the relationship between rapid head movement and eye movement in the plane of the channels is examined. This test was performed with a Micromedical Technologies brand EyeSeeCam model v-HIT device. During the test, the child puts on glasses with a camera that records eye movements. The patient is then asked to look at a fixed target. While the patient's eyes are fixed on the target, the tester quickly turns the patient's head 20°-30° in the test plane. Meanwhile, eye movements are recorded, and these movements are analyzed by the computer. As a result of the test, the VOR gain ratio, the presence of saccades, and the percentage of asymmetry are evaluated. While the gain value represents the ratio between head speed and eye speed, the asymmetry value is a value representing the difference between the VOR gains of the symmetrical canals between the ears. A VOR gain less than 0.8, a percentage of asymmetry greater than 6.9, and the presence of saccade are considered pathological v-HIT responses.[16]

Vestibular Evoked Myogenic Potential Test: The test was performed with a Neurosoft brand Neuro-Audio model device. In the c-VEMP test, the electrodes are placed on the sternum, the reference electrode is placed in the middle 1/3 of the sternocleidomastoid muscle (SCM), and the ground electrode is placed on the nasion point in the midline on the forehead, and the SCM is requested to contract by turning the head.

In the o-VEMP test, electrodes are placed in the middle of the forehead, 15-20 mm below the orbits, and on the cheeks. The child is asked to look up, and the N1 and P1 absolute latencies, N1-P1 inter-latency, N1-P1 amplitude, and asymmetry percentage (which represents the ratio of the amplitudes of the waves formed between the two ears) of the obtained waves are evaluated and recorded. Prolonged wave latencies, increased asymmetry rates, or failure to obtain VEMP waves are considered as pathological.[17] While c-VEMP mainly evaluates saccular function and vestibulo-colic reflex, o-VEMP evaluates utricular function and VOR.

Statistical Analysis

Qualitative data from the variables included in the study were expressed as numbers (percentages). The Shapiro–Wilk test was used to assess the conformity of quantitative data with the normal distribution. Data that did not show a normal distribution were expressed as median (minimum-maximum), and data with a normal distribution were expressed as mean ± standard deviation. Mann–Whitney *U*-test, independent samples *t*-test, Yates' corrected chi-square test, and Fisher's exact chi-square test were used for statistical analysis where appropriate. A value of $P < .05$ was considered statistically significant in the statistical analyses applied. All analyses were performed with IBM Statistical Package for the Social Sciences Statistics version 26.0 for Windows (IBM SPSS Corp.; Armonk, NY, USA).

Results

The participants in the study consisted of 2 groups: the SLD group (n = 30) consisting of children diagnosed with SLD and the control group (n = 30) consisting of healthy children.

The mean age of the study group was determined as 9.53 ± 1.63 and the control group as 9.37 ± 2.13.

In the participants who are included in the study, 33.33% (n = 10) of the children in the study group and 43.33% (n = 13) of the children in the control group were girls, and both groups were found to be similar in terms of gender and age variables. The comparison of sex and age according to their distribution between groups is shown in Table 1 ($P = .425$, $P = .735$, respectively).

The VNG test results were compared between the groups. No pathological findings were observed in the gaze test, pursuit test, saccade test, spontaneous nystagmus test, and positional test values of both groups. There was a significant difference between the SLD and control groups between the optokinetic test and head shake test values. Information on VNG test results is given in Table 2 ($P = .001$, $P = .038$, respectively).

In v-HIT, no statistically significant difference was found between groups in terms of lateral, anterior, and posterior SCC gains, as well as left anterior-right posterior, right anterior-left posterior, and horizontal asymmetry ratios.

There was a statistical difference between the groups in the lateral asymmetry value. Gain and asymmetry values in v-HIT applied to the participants included in the study are given in Table 3 ($P = .016$).

There was no statistically significant difference in the comparison of wave presence between groups in the c-VEMP and o-VEMP tests.

Table 1. Comparison of Demographic Variables Between Groups

		Group		
		SLD (n = 30)	Control (n = 30)	*P*
Variables		n (%)		
Sex	Female	10 (33.33)	13 (43.33)	.425*
	Male	20 (66.67)	17 (56.67)	
Age		Median (min-max)		
		9 (7-14)	9 (7-14)	.735**

Max, maximum; Min, minimum; SLD, specific learning disorder.
*Yates's correction chi-square test; **Mann–Whitney *U*-test.

Table 2. Comparison of VNG Test Results Between Groups

		Group		
		SLD (n = 30)	Control (n = 30)	*P*
VNG Subtests		n (%)		
Spontaneous nystagmus	Normal	30 (100.00)	30 (100.00)	
	Abnormal	0 (0.00)	0 (0.00)	
Gaze	Normal	30 (100.00)	30 (100.00)	
	Abnormal	0 (0.00)	0 (0.00)	
Saccade	Normal	30 (100.00)	30 (100.00)	
	Abnormal	0 (0.00)	0 (0.00)	
Pursuit	Normal	30 (100.00)	30 (100.00)	
	Abnormal	0 (0.00)	0 (0.00)	
Optokinetic	Normal	21 (70.00)	30 (100.00)	**.001***
	Abnormal	9 (30.00)	0 (0.00)	
Positional tests	Normal	30 (100.00)	30 (100.00)	
	Abnormal	0 (0.00)	0 (0.00)	
Head shake	Normal	27 (90.00)	30 (100.00)	**.038***
	Abnormal	3 (10.00)	0 (0.00)	

SLD, specific learning disorder; VNG, videonystagmography.
*Fisher's exact chi-square. Bold values indicate significant.

Table 3. Comparison of Video Head Impulse Test Values Between Groups

		Group		
	Semicircular Canal	SLD (n = 30)	Control (n = 30)	*P*
		Mean ± SD		
Gain	Lateral	0.91 ± 0.10	0.94 ± 0.08	.061*
	Anterior	0.83 ± 0.11	0.85 ± 0.12	.333*
	Posterior	0.83 ± 0.11	0.86 ± 0.12	.158*
Asymmetry		Median (min-max)		
	Lateral	4.5 (0-11)	3 (1-8)	**.016****
	LARP	4 (1-18)	6 (1-13)	.193**
	RALP	3 (1-13)	3 (1-15)	.864**

Data are given as mean ± standard deviation or median (minimum-maximum) according to normality of distribution.
LARP, left anterior-right posterior; Max, maximum; Min, minimum; RALP, right anterior-left posterior; SD, standard deviation; SLD, specific learning disorder.
*Independent samples *t*-test; **Mann–Whitney *U*-test. Bold values indicate significant.

The comparison of the wave presence between the groups in the c-VEMP and o-VEMP tests is given in Table 4 ($P = 1.000$ and $P = 1.000$, respectively).

In the c-VEMP test, P1 latency and asymmetry values, P1 latency, N1-P1 interlatency, N1 latency, and N1-P1 amplitude values of both groups were found to be similar, whereas the difference in N1 latency, P1-N1 amplitude values, P1-N1 interlatency, and asymmetry values was statistically significant between groups. The latency values, interlatency values, amplitude values, and asymmetry rates between the waves obtained in the c-VEMP and o-VEMP tests applied to the participants in the study are given in Table 5.

Discussion

In the evaluation of 30 children diagnosed with SLD and 30 age-sex-matched healthy children included in our study, optokinetic and head shake test values in VNG subtests were found to be pathological in the study group, and the lateral asymmetry value in v-HIT was found to be significantly higher in the study group. Also, a significant difference was found in the N1 latency, P1-N1 interlatency, and P1-N1 amplitude values in the c-VEMP test and in the asymmetry values in the o-VEMP test.

Looking at the literature, previous studies suggest that vestibular dysfunction may accompany psychiatric disorders.[18,19] A recent meta-analysis highlighted the possible existence of vestibular dysfunctions in children with intellectual disability, attention deficit hyperactivity disorder (ADHD), autism spectrum disorder, and SLD.[13] Narciso et al[20] examined vestibular variations in children. They reported that 47% of the participants had complaints about their performance at school. As a result of this study, the authors suggested that vestibular disorders may be related to motor disorders and learning. Previous functional imaging studies in humans and animal studies have shown that vestibular information feeds cortical networks that serve visuospatial processing, spatial memory and even numerical ability, that vestibular loss of these neural connections may be associated with weaker cognitive ability.[21]

Table 4. Comparison of Wave Presence Between Groups in c-VEMP and o-VEMP test

		Group		
		SLD (n = 30)	Control (n = 30)	
		n (%)		*P**
c-VEMP	Wave (+)	29 (96.67)	29 (96.67)	**1.000**
	Wave (–)	1 (3.33)	1 (3.33)	
o-VEMP	Wave (+)	28 (93.33)	29 (96.67)	**1.000**
	Wave (–)	2 (6.67)	1 (3.33)	

c-VEMP, cervical vestibular evoked myogenic potential; o-VEMP, ocular vestibular evoked myogenic potential; SLD, specific learning disorder
*Fisher's exact chi-square. Bold values indicate significant.

Table 5. Comparison of c-VEMP and o-VEMP Test Values Between Groups

		Group		
		SLD (n = 30)	Control (n = 30)	*P*
c-VEMP	P1 latency	13 (11.2-14.4)	13.1 (12-16.1)	.396**
	N1 latency	20.9 ± 1.43	22.26 ± 2.36	**.011***
	P1-N1 interlatency	7.84 ± 1.37	8.94 ± 1.88	**.014***
	P1-N1 amplitude	75.6 (21-200.8)	71.5 (30.5-198.2)	.320**
	Asymmetry	7.8 (0.1-29)	7 (0.6-20.1)	.266**
o-VEMP	P1 latency	15 (12.7-19.1)	15.1 (14-18.3)	.467**
	N1 latency	9.45 (8.4-12.1)	9.8 (8.6-12.5)	.073**
	P1-N1 interlatency	5.73 ± 0.87	5.43 ± 1.07	.268*
	P1-N1 amplitude	7.6 (2.3-21.6)	6.8 (3.2-29.5)	.743**
	Asymmetry	14.6 (4.4-61.2)	7.6 (0.4-27.1)	**.010****

Data are given as mean ± standard deviation or median (minimum-maximum) according to normality of distribution.
c-VEMP, cervical vestibular evoked myogenic potential; o-VEMP, ocular vestibular evoked myogenic potential; SLD, specific learning disorder.
*Independent samples *t*-test, **Mann–Whitney *U*-test. Bold values indicate significant.

Reading requires necessary eye movements, saccade movements, and periods of fixation. Following the teacher, transcribing the lessons on the blackboard, reading textbooks is the result of a number of functions that require the integrity of both oculomotor functions and vestibular interconnections.[22] Studies examining the relationship between nystagmus and SLD, which indicate the pathology in this pathway, are limited. For example, Ayres[23] evaluated nystagmic movements in post-rotational stimulation in children with learning disabilities and stated that post-rotational nystagmus was exacerbated in 13% of these children. In a study conducted in 2000, Ganança[24] et al showed that 20% of children with low school performance had pathology under computed nystagmography. In a prospective study, 88 children aged between 7 and 12 were consulted to otorhinolaryngology for vestibular examinations and hearing tests; 49% were underperforming at school, whereas 51% of them had no difficulties. On vestibular examination, 32.60% of the underperforming children had normal results, whereas 73.33% of the children performing well at school had normal findings.[25]

In our study, optokinetic and head shake tests, which are VNG subtests, were found to be significantly pathological in the SLD group, and this finding supports the presence of impaired eye movements in SLD. The optokinetic system maintains the image of the target while the environment is in motion; the head shake is achieved by oscillating the head in the horizontal plane at a high frequency (2 Hz); and the detection of nystagmus in both tests reflects vestibular abnormalities. While gaze, saccade, and pursuit tests were normal in our study, the significant difference between the healthy control group and the SLD group in the optokinetic test may be related to the difficulty of the test and the inability of the children to cooperate in the test. However, considering that previous studies do not include current data, we think that our study will contribute to the literature in this respect.

It has previously been hypothesized that vestibular dysfunctions may inhibit the sequential eye fixation required for reading.[25] In our study, the lateral asymmetry value in v-HIT, which basically evaluated the VOR, was found to be significantly higher in the SLD group, but the mean value was not above the pathological limit. This finding suggested that the functions of the lateral SCC are affected, although not at a pathological level, and may affect the eye fixation required for functions such as reading and writing. In our study, asymmetry was observed in the lateral canals and not detected in the anterior and posterior regions. This finding also supports the hypothesis of Caldani et al[18] that VOR abnormalities do not affect SCCs equally and that the best response is seen in the lateral canal.

The o-VEMP/c-VEMP is used as an auxiliary test battery in the evaluation of peripheral vestibular pathologies and central pathologies affecting the brainstem, as it also provides information about the function of parts such as otolith organs, vestibular nerve, and brain stem.[26] The c-VEMP/o-VEMP waveform corresponds to a composite and mean myogenic response that may be evoked by high-intensity sounds or vibrations.[27]

In the c-VEMP and o-VEMP tests applied in this study, no difference was found in terms of the presence of waves. The c-VEMP P1-N1 interlatency, N1 latency, P1-N1 amplitude values, and o-VEMP asymmetry values were statistically significant between the groups. This influence indicates that the neural system in the VEMP arc is affected in SLD, and there are changes in the neural circuits that produce these responses.

As far as we know, there is no study in the literature examining VEMP in SLD. However, in a study examining c-VEMP in 13 children diagnosed with ADHD, it was reported that there was an altered c-VEMP response, which may contribute to deficiencies in posture and balance performance in children with ADHD.[28]

Specific learning disorders with any psychiatric diagnosis or ADHD were not included in our study. In this case, it comes to mind that conditions such as low birth weight and prenatal hypoxia, which frequently play a role in the etiology of SLD, may affect the vestibular arch and impair conduction and may be indirectly responsible for changes in VEMP parameters. It has also previously demonstrated the presence of the asymmetric tonic neck reflex (a primitive reflex found in newborns and normally disappears at about 6 months of age) in children with ADHD, SLD, and emotional and behavioral problems.[29,30] This may also be related to the pathological result observed in c-VEMP measured from neck muscles in our patients.

The study also has some strengths and limitations. First of all, this study is one of the limited number of studies investigating comprehensive vestibular assessment in SLD patients. The exclusion of medical conditions by including patients diagnosed with pure SLD is one of the strengths of this study. In addition, the exclusion of additional psychiatric conditions with a structured interview and the fact that the patients did not use any medication is another strength of this study. The relatively small sample size and the inability to distinguish structural changes using a functional imaging technique are among the limitations of this study. In addition, the fact that children and adolescents are in the same sample group is another limitation of the study.

In conclusion, this study showed that vestibular functions may differ from normal in SLD patients and that vestibular dysfunction may play a role in symptoms such as postural instability, gross, balance, and fine motor disorders that are frequently observed in these children. However, there is limited information in the literature about the reasons for this. Further studies are needed to add neuroimaging-based studies to the neurophysiological evaluation of the vestibular system and to clarify the relationship between vestibular dysfunction and other motor dysfunctions in these children. Moreover, in order to better understand the potential relationship and characteristics of the vestibular system and SLD, it is thought that there is a need for more comprehensive studies with a larger sample size, also better including a vestibular evaluation in addition to a standard neuropsychiatric examination.

Ethics Committee Approval: *Ethical approval was obtained from the Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (Approval no: 2021/2335).*

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