Original Article

Frequency of central auditory processing disorder in attention deficit hyperactivity disorder and specific learning disorder

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ABSTRACT

Objectives: This study aims to investigate the prevalence of individuals with central auditory processing disorder (CAPD) among children with neurodevelopmental disorder, to establish whether there is an objective screening test parameter that identifies individuals with neurodevelopmental disorder without CAPD, and to scan the history of these individuals for a unique feature.

Patients and Methods: The study included 94 patients (69 males, 25 females; mean age 8.5±1.2 years; range, 7 to 13 years) with specific learning disorder (SLD) and/or attention deficit hyperactivity disorder (ADHD). After assessment by child and adolescent psychiatry, the Staggered Spondaic Word (SSW) test was performed in addition to a full audiologic evaluation.

Results: Twenty-four patients (27.2%) with SLD and/or ADHD had CAPD according to SSW criteria. Twenty-eight patients had SLD, 27 had ADHD, and 39 had mixed-type neurodevelopmental disorder. Central auditory processing disorder rate was significantly higher in the mixed group than in the ADHD group ($p<0.05$). There was a significant relationship between term birth and the absence of CAPD. Auditory Brainstem Response test revealed a significant correlation between the III-V wave interval evaluation in the left ear and CAPD frequency.

Conclusion: A significant proportion of patients with SLD and/or ADHD in this study had CAPD. Patients with mixed-type neurodevelopmental disorder in particular were at risk for CAPD. Success of rehabilitation may increase if combined with CAPD-specific programs.

Keywords: Attention deficit hyperactivity disorder; auditory perception; child; hearing tests; language development disorders; specific learning disorder.

Neurodevelopmental disorders are a spectrum that contain specific learning disorder (SLD) and attention deficit hyperactivity disorder (ADHD). In this spectrum, these disorders can be found together or individually.

Specific learning disorder is a neurodevelopmental disorder characterized by persistent difficulties that impair learning foundational academic skills in reading, writing and/or mathematics (American Psychological Association [APA] 2013). The disorder cannot be accounted for by intellectual disability, uncorrected visual or auditory acuity, other mental or neurologic disorders, psychosocial adversity, or lack of proficiency in the language of academic instruction or inadequate

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educational instruction. It is suggested that SDL has a biologic origin in which genetic, epigenetic, and environmental factors influence each other and in turn affect brain mechanisms related with learning processes.

According to the APA, ADHD[1] or hyperkinetic disorder[2] is a chronic neurodevelopmental disorder that can have a profound impact at school[3,4] and workplace,[5-8] as well as on relationships.[5,6,9] As a consequence, the quality of life of individuals with ADHD and that of people around them may be impaired.[3,10-13]

Central auditory processing consists of sound localization and lateralization, auditory identification, defining auditory patterns, auditory performance in the presence of other stimuli, and degenerated acoustic stimulus. Central auditory processing disorder (CAPD) is defined as a deficit in one or more of these processes, although with normal mental capacity and peripheral audition, and its prevalence is 2-3% among children.[14,15]

In this study, we aimed to investigate the prevalence of individuals with CAPD among children with neurodevelopmental disorder, to establish whether there is an objective screening test parameter that identifies individuals with neurodevelopmental disorder without CAPD, and to scan the history of these individuals for a unique feature.

PATIENTS AND METHODS

This study was conducted at Bakırköy Dr. Sadi Konuk Training and Research Hospital between August 2017 and June 2018. The study included 94 patients (69 males, 25 females; mean age 8.5±1.2 years; range, 7 to 13 years) with SLD and/or ADHD. All patients with SLD had a documented history of dyslexia/SLD, as reported by their school, and reading impairment, as determined in a standardized test. Diagnosis of ADHD and SLD was established by two different child and adolescent psychiatrists, according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.

All patients with SLD and/or ADHD who scored >85 in standardized intelligence quotient (IQ) tests were monolingual Turkish speakers and had no significant medical, neurologic, or other psychiatric illnesses. Children with a history of neurodevelopmental disability; congenital or acquired neurologic disorder such as a traumatic brain injury, a disease that affected brain function, or known history of birth complications; or a diagnosis of visual or hearing impairment were excluded.

Before full audiological assessment, six patients with audiogram levels above 15 dB were excluded. Patients were divided into three groups as SLD (n=28, 29.8%), SLD with ADHD (n=39, 41.5%), and ADHD (n=27, 28.7%). After assessment by child and adolescent psychiatry, the Staggered Spondaic Word (SSW) test was performed in addition to a full audiologic evaluation (Auditory Brainstem Response [ABR], Distortion Product Otoacoustic Emission [DPOAE], Transient Otoacoustic Emission [TOAE], Tympanogram and Acoustic Reflex test). The corrected error percentages of SSW test positions were reported, which were obtained from patients with SSW norms and any error percentages over the SSW norm were investigated.

The SSW test is the most common test to assess central auditory processing function among children.[14,15] This test was established by Katz.[16] The test is composed of two spondees with a staggered onset. The last half of the first spondee and the first part of the second spondee segments are presented in isolation to the opposite ear. This is a 40-item test and reversals and ear-order effect were monitored according to Katz's methodologies. The SSW test was translated to Turkish and validated by Akdas.[17] The SSW tests were conducted in a soundproof booth using an Otometrics Madsen Astera 2 audiometer (Otometrics A/S., Taastrup, Denmark); a computer containing Auditory Processing tests was used. The SSW tests were performed at 50 dB sensation level, above the average of 500 Hz, 1 kHz, and 2 kHz. The method developed by Katz[16] was used to standardize test scores. The study protocol was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Ethics Committee (Date: 08.14.2017, No: 2017-09-03). A written informed consent was obtained from patients' parents. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical analysis

All analyses were performed using the MedCalc Statistical Software version 12.7.7 (MedCalc Software bvba, Ostend, Belgium. Descriptive statistics were used to define constant variables (mean, standard deviation, minimum, median, maximum). The comparison of two independent variables accordant with normal distribution was performed using the Student's t-test. The comparison of two dependent variables incompatible with normal distribution was performed using the Mann-Whitney U test. Statistical significance was set at $p<0.05$.

RESULTS

Twenty-eight patients had SLD, 27 had ADHD, and 39 had mixed-type neurodevelopmental disorder. Demographic characteristics of the patients are summarized in Table 1. Twenty-four patients (27.2%) with SLD and/or ADHD were found to have CAPD according to SSW criteria.

Central auditory processing disorder was found in 21.4% (n=6) in the SLD group, 14.8% (n=4) in the ADHD group, and 35.8% (n=14) in mixed group. Rate of CAPD was statistically significantly higher in the mixed group than in the ADHD group ($p<0.05$), while there was no statistically significant difference between the SLD and mixed group, or the ADHD and SLD group ($p>0.05$) (Table 2).

We evaluated patients' demographic characteristics in terms of speech disorder, delayed speech, preterm/term/post-term birth, delayed speech in family history, and SLD presence in family history, and the connection of these characteristics with CAPD. Statistical evaluation revealed a statistically significant relationship between term birth and the absence of CAPD; no significant relationship was found between other demographic characteristics and CAPD (Table 3). In addition, we investigated whether there was a statistically significant relationship between CAPD and objective test findings. Analyses of ABR test findings for

Table 1. Demographic characteristics of patients

	n	%	Mean±SD	Median	Min-Max
Age (year)			8.5±1.2	8	7-13
Income (monthly; ₺)			1,978.9±962.3	1,650	1,000-7,000
Gender					
Female	25	26.6			
Male	69	73.4			
Group					
Specific learning disorder	28	29.8			
Attention-deficit hyperactivity disorder	27	28.7			
Mixed-type disorder	39	41.5			
Mother's education level					
Unspecified	3	3.2			
Elementary school	60	63.8			
High school-college	22	23.4			
University	3	3.2			
No reading and writing	6	6.4			
Father's education level					
Unspecified	1	1.1			
Elementary school	57	60.6			
High school-college	29	30.9			
University	4	4.3			
No reading and writing	3	3.2			

SD: Standard deviation; Min: Minimum; Max: Maximum.

Table 2. Comparison of central auditory processing disorder rates

	SLD (n=28)		Mixed (n=39)		
	n	%	n	%	p
Central auditory processing disorder	6	21.4	14	35.8	0.07
	ADHD (n=27)		Mixed (n=39)		
	n	%	n	%	p
Central auditory processing disorder	5	14.8	14	35.8	0.038
	SLD (n=28)		ADHD (n=27)		
	n	%	n	%	p
Central auditory processing disorder	6	21.4	5	14.8	0.76

SLD: Specific learning disorder; ADHD: Attention deficit hyperactivity disorder.

I, III, and V wave lengths as well as I-III, III-V, and I-V wave intervals separately in both ears to determine whether there was a meaningful relationship with CAPD showed a statistically significant correlation between the III-V wave interval evaluation in the left ear and CAPD frequency (Table 4).

Moreover, analyses for any significant relationship between CAPD and DPOAE 1, 1.4, 2, 2.8, 4, and 6 Hz, and TOAE 1, 1.4, 2, 2.8, and 4 Hz tests demonstrated no statistically significant relationship between otoacoustic emission tests and CAPD.

DISCUSSION

Many children around the world who are sent to counseling and research centers due to having below-average academic skills may then be sent to child and adolescent psychiatry specialists and diagnosed as ADHD or SLD. During this process, otolaryngologists perform standard audiometric scans to detect hearing

Table 3. Comparison of demographic features by groups organized according to staggered spondaic word test

	Normal		Impaired		
	n	%	n	%	p
Speech impairment					
Absent	50	71.4	19	79.2	0.595
Present	20	28.6	5	20.8	
History of delayed speech					
Absent	46	65.7	16	66.7	0.999
Present	24	34.3	8	33.3	
Dyslexia in family					
Absent	41	59.4	12	50.0	0.478
Present	28	40.6	12	50.0	
Delayed speech in family					
Absent	44	62.9	17	70.8	0.622
Present	26	37.1	7	29.2	
Labor					
Mature	56	80.0	21	87.5	0.018
Premature	12	17.1	0	0.0	
Postmature	2	2.9	3	12.5	

Fisher's exact p.

Table 4. Comparison of brainstem evoked response audiometry parameters by groups impaired in terms of Staggered Spondaic Word test

	Normal			Impaired			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
Right							
I	1.66±0.28	1.6	1.2-2.56	1.82±0.39	1.71	1.34-2.56	0.141
III	3.84±0.34	3.78	2.84-4.9	3.98±0.65	3.9	1.72-4.9	0.054
V	5.72±0.35	5.7	4.76-6.82	5.83±0.53	5.88	4.2-6.6	0.161
I-V	4.06±0.37	4.1	3.3-4.92	4.14±0.56	3.98	3.3-6.2	0.828
I-III	2.17±0.33	2.19	1.18-3.3	2.3±0.54	2.3	1.48-4.48	0.156
III-V	1.9±0.33	1.9	1.1-3.08	1.92±0.31	1.9	1.24-2.48	0.788
Left							
I	1.79±1.62	1.57	0.92-15	2.15±2.75	1.6	1.26-15	0.993
III	3.85±0.27	3.78	3.2-4.48	3.95±0.44	3.82	3.26-5.06	0.512
V	5.71±0.29	5.7	4.76-6.26	5.73±0.48	5.69	4.76-6.78	0.921
I-V	4.12±0.3	4.17	3.5-4.76	4.17±0.42	4.13	3.5-5.18	0.855
I-III	2.25±0.31	2.2	1.6-3.1	2.38±0.44	2.3	1.58-3.46	0.169
III-V	2.06±1.69	1.89	1.2-15.8	1.75±0.21	1.72	1.38-2.28	0.028

SD: Standard deviation; Min: Minimum; Max: Maximum; Mann-Whitney U test.

loss; however, it is impossible to diagnose CAPD with standard hearing tests because the clinical signs are the same; it is challenging to clinically distinguish patients with neurodevelopmental disorder and CAPD.

Likewise, Dawes and Bishop[18] reported that symptoms of CAPD and neurodevelopmental disorder spectrum were similar to each other. Identifying micro lesions in the auditory central nervous system or functional processing disorders with radiologic and neurologic screening is impossible.[5] Speech and mental tests can prove that speech skills and mental capacity is within normal range, but cannot show with any degree of certainty that it is associated with CAPD. Pure tone audiometer, TOAE, DPOAE, tympanogram, and acoustic reflex are all screening tests for peripheral hearing tests, so they cannot provide information about processing. Therefore, CAPD is a special disorder that needs several proper tests for diagnosis.

The determination of CAPD is important for making appropriate treatment plans. However, screening for CAPD comprises tests that may be complicated by deterioration of linguistic test material.[19] In this manner, the diagnosis is established by detecting the understanding of the linguistic test material by the patient.

Our study has some limitations. Firstly, the sample size was small. Secondly, the SSW test used for the diagnosis of CAPD was not crosschecked with other diagnostic tests. And lastly, the patients were composed only of ADHD and SLD patients and other neurodevelopmental disorder patients were not included.

In conclusion, although it is challenging to clinically distinguish patients with neurodevelopmental disorder and CAPD, our finding regarding the III-V wave interval in the left ear may be important for diagnosis or screening and requires further studies. A significant proportion of patients with SLD and/or ADHD in this study had CAPD and patients with mixed-type neurodevelopmental disorder in particular were at risk for CAPD. Therefore, success of rehabilitation may increase if combined with CAPD-specific programs.

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