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Original Research

Evaluation of the Optic Nerve in Children with Attention Deficit Hyperactivity Disorder Using Shear Wave Elastography

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ABSTRACT

Objective: Attention-Deficit/Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder associated with structural and microfunctional alterations of the central nervous system. As the optic nerve is an extension of the CNS, this study evaluated optic nerve stiffness in children with ADHD using shear wave elastography (SWE) and investigated its potential as a non-invasive imaging biomarker.

Methods: This prospective case-control study included 74 children aged 6–15 years: 37 diagnosed with ADHD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria and 37 age- and sex-matched healthy controls. Bilateral optic nerve sheath diameter (ONSD) and SWE measurements were performed using a high-resolution ultrasound system with a 9-MHz linear transducer. A region of interest was positioned approximately 5 mm posterior to the optic disc. Three consecutive stiffness measurements were obtained from each optic nerve, and the mean value (kPa) was used for analysis. Group comparisons and receiver operating characteristic (ROC) curve analyses were performed.

Results: Age, sex distribution, and ONSD measurements did not differ significantly between the groups (all $p > 0.050$). In contrast, optic nerve stiffness was significantly higher in the ADHD group than in controls for both eyes (all $p < 0.001$). Mean right optic nerve stiffness was 25.31 ± 13.37 kPa versus 5.70 ± 3.02 kPa, and mean left optic nerve stiffness was 24.84 ± 13.79 kPa versus 5.63 ± 2.73 kPa in the ADHD and control groups, respectively. Mean bilateral stiffness was also significantly higher in the ADHD group (25.27 ± 12.80 vs. 5.55 ± 2.54 kPa, $p < 0.001$). ROC analysis demonstrated excellent diagnostic performance, with AUC values of 0.978, 0.971, and 0.975 for the right, left, and mean bilateral stiffness measurements, respectively.

Conclusion: Children with ADHD demonstrated significantly increased optic nerve stiffness despite having normal optic nerve sheath diameters. These findings suggest that ADHD may be associated with microstructural and biomechanical alterations of the optic nerve. SWE appears to be a promising, non-invasive, and reproducible imaging modality that may contribute to the development of novel imaging biomarkers in ADHD and other neurodevelopmental disorders.

Keywords: attention-deficit/hyperactivity disorder, optic nerve, shear wave elastography, ultrasonography

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a common childhood neurodevelopmental disorder characterized by persistent symptoms of inattention, hyperactivity, and impulsivity that may impair academic, social, and behavioral functioning [1]. Although the pathophysiology of ADHD is complex, it is well-established that genetic predisposition and environmental factors, alongside alterations in the prefrontal cortex, basal ganglia, cerebellum, and white matter microstructure, play a critical role in this process [2]. Recent studies have suggested that the retinal and optic nerve, as an anatomical extension of the central nervous system (CNS), may serve as an accessible and valuable "window" for monitoring microvascular and neurodegenerative changes within the brain [3,4].

Optic nerve sheath diameter (ONSD) and optic nerve morphology have long been used parameters in the assessment of increased intracranial pressure and various systemic inflammatory processes [5,6]. While conventional B-mode ultrasonography provides valuable information about anatomical structures, it is insufficient in providing objective data on the mechanical properties and stiffness of tissue [7]. Shear Wave Elastography (SWE) has emerged as a valuable non-invasive, real-time, and reproducible imaging modality that enables quantitative assessment of tissue stiffness. [8].

The effectiveness of SWE in the evaluation of optic nerve involvement has been demonstrated across various pathologies in the literature. For instance, it has been reported that optic nerve stiffness is significantly higher in patients with Behçet's disease compared to healthy controls, suggesting that this increase in stiffness may serve as an early indicator of neural involvement [9]. Similarly, characteristic alterations in the elasticity moduli of the optic nerve and retrobulbar structures have been identified in conditions such as diabetic retinopathy and glaucoma [10,11]. While research to date has primarily focused on parameters such as brain volume and cortical thickness in ADHD, the use of SWE to examine the biomechanical properties of the optic nerve is an area that has not yet been sufficiently researched [12,13]. We hypothesized that the neurodevelopmental differences observed in children with ADHD may also be reflected in the structural and biomechanical properties of the optic nerve, which is an extension of the central nervous system.

This study aims to evaluate optic nerve stiffness in children diagnosed with ADHD using the SWE method, to investigate the potential impact of this neurodevelopmental disorder on optic nerve tissue, and to explore the potential of SWE as a supplementary diagnostic biomarker in the clinical assessment of ADHD.

Main Points

- Children with ADHD demonstrated significantly higher optic nerve stiffness measured by shear wave elastography than healthy controls.
- Optic nerve sheath diameter did not differ between ADHD and control groups, indicating that SWE detects changes not visible with conventional ultrasonography.
- Optic nerve stiffness showed excellent diagnostic performance for distinguishing children with ADHD from healthy controls (AUC = 0.975).
- Shear wave elastography may serve as a promising, non-invasive imaging biomarker for microstructural optic nerve alterations associated with ADHD.

MATERIALS AND METHODS

Study Design

This prospective case-control study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Clinical Research Ethics Committee of Kahramanmaraş Sütçü İmam University Faculty of Medicine (Approval number: 2023/10-07, Date: September 20, 2023). Written informed consent was obtained from the parents of all participating children before any procedures were performed.

Participants

The study included 37 children diagnosed with ADHD and 37 healthy controls, for a total of 74 participants. The ADHD group consisted of children aged 6–15 years who had been diagnosed with ADHD according to DSM-5 criteria. The control group consisted of age- and sex-matched healthy children.

The children included in the ADHD and healthy control groups were evaluated according to the following clinical and eligibility criteria. An ADHD diagnosis was established by a child and adolescent psychiatrist with 15 years of clinical experience, following a comprehensive psychiatric evaluation using the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS), a semi-structured diagnostic interview [14]. Children in the ADHD group

with comorbid psychiatric diagnoses, or who were taking or had previously taken psychiatric or other medication, were excluded from the study. Children in the healthy control group with any psychiatric diagnosis or taking any psychiatric medication were also excluded. Children with neurodevelopmental, neurological, or ophthalmological disorders, or who were receiving treatment for any medical condition, were excluded from both groups. All participants underwent a routine ophthalmological examination within the last month. Children with a history of ocular trauma, glaucoma, refractive errors greater than ± 0.50 dioptres, orbital disease or any systemic condition that could affect optic nerve elasticity (e.g. Behçet's disease or diabetes) were excluded from both groups.

Ultrasonographic and Shear Wave Elastography Evaluation

All radiological examinations were performed by a single experienced radiologist to ensure inter-examiner consistency. A high-resolution GE Logiq E9 (GE Healthcare, Milwaukee, WI, USA) ultrasound system, equipped with a 9 MHz high-frequency linear array transducer, was utilized for all measurements.

Optic Nerve Sheath Diameter Measurement: Participants were examined in the supine position with their eyes closed and maintained in a neutral gaze. To minimize pressure on the globe and prevent potential artifacts, a generous amount of acoustic coupling gel was applied. The ONSD was measured bilaterally in the longitudinal plane, 3 mm posterior to the globe, where the contrast between the hypoechoic optic nerve and the surrounding hyperechoic sheath is most distinct (Figure 1).

Shear Wave Elastography Protocol: SWE was performed using the same transducer while participants were examined in the supine position with their eyes closed and maintained in a neutral gaze. A generous amount of acoustic coupling gel was applied to minimize pressure on the globe and potential artifacts. For SWE assessment, the region of interest (ROI) was consistently positioned within the optic nerve approximately 5 mm posterior to the optic disc to standardize the measurement location. Three consecutive stiffness measurements were obtained from both the right and left optic nerves, and the mean of the three measurements was used for subsequent analysis (Figure 2). Optic nerve stiffness was recorded in kilopascals (kPa). The mean stiffness value for each eye and the overall mean stiffness value obtained from both eyes were calculated for statistical analysis. The radiologist performing the examinations and SWE measurements was blinded to the clinical group of the participants.

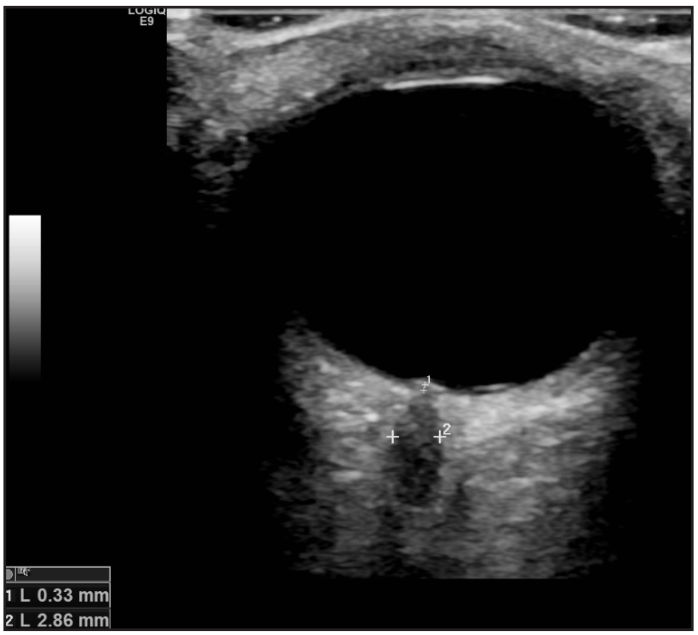

Figure 1. Ultrasonographic measurement of optic nerve sheath diameter.

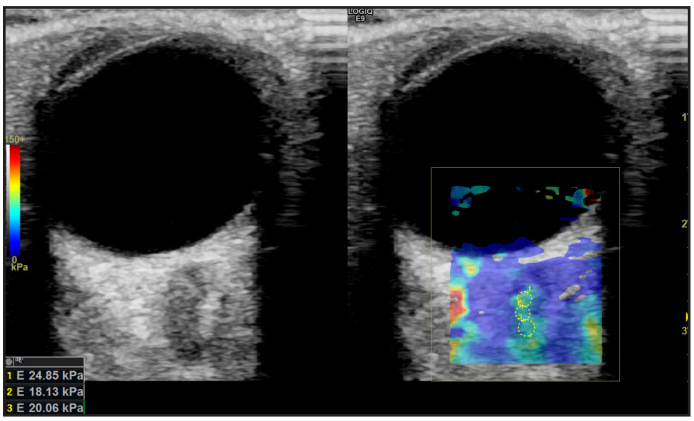

Figure 2. B-mode ultrasonography (left) and corresponding shear wave elastography image (right) demonstrating optic nerve stiffness assessment. Three circular ROIs were positioned within the optic nerve, and mean stiffness values were measured in kilopascals (kPa).

Statistical Analysis

Descriptive statistics were utilized to summarize the data, including mean, standard deviation, minimum, maximum, frequency, and percentage values. The normality of the distribution for continuous variables was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. For the analysis of independent quantitative data, the Independent Samples t-test was employed for variables showing a normal distribution. At the same time, the Mann-Whitney *U* test was used for those who did not meet the normality criteria. Categorical (qualitative)

independent variables were analyzed using the Chi-square test. The diagnostic efficacy, effect levels, and optimal cut-off values were evaluated using the Receiver Operating Characteristic (ROC) curve analysis. All statistical procedures were performed using SPSS version 27.0 software (IBM Corp., Armonk, NY, USA). A *p*-value of less than 0.050 was considered statistically significant.

RESULTS

The ages of the individuals included in the study ranged from 6.0 to 15.0 years, with an overall mean age of 9.8 ± 2.7 years. Of the total participants, 27 (36.5%) were female, and 47 (63.5%) were male. (Table 1) There was no statistically significant difference in age between the control group (9.59 ± 2.63 years) and the ADHD group (9.95 ± 2.76 years) ($p = 0.577$). Regarding gender distribution, the control group consisted of 45.9% females (n = 17) and 54.1% males (n = 20), while the ADHD group consisted of 27.0% females (n = 10) and 73.0% males (n = 27); no significant difference was observed between the groups ($p = 0.091$) (Table 1).

The mean right ONSD value was 2.92 ± 0.23 mm in the control group and 2.92 ± 0.29 mm in the ADHD group, while the mean Left ONSD value was 2.96 ± 0.29 mm and 2.98 ± 0.25 mm, respectively. No significant differences were observed in either right or left ONSD measurements between the ADHD and control groups (both $p > 0.050$).

In terms of elastographic assessment, the ADHD group demonstrated significantly higher stiffness values for the right eye, left eye, and mean bilateral measurements than the control group. The right eye stiffness value was significantly higher in the ADHD group (25.31 ± 13.37 kPa) than in the control group (5.70 ± 3.02 kPa) ($p < 0.001$). Similarly, the left eye stiffness value was significantly higher in the ADHD group (24.84 ± 13.79 kPa) compared with the control group (5.63 ± 2.73 kPa) ($p < 0.001$) (Table 1). Furthermore, the mean bilateral eye stiffness value was significantly higher in the patient group (25.27 ± 12.80 kPa) than in the control group (5.55 ± 2.54 kPa) ($p < 0.001$) (Figure 3).

The optimal cut-off value was determined using the Youden index, which is a statistical method that maximises the sum of sensitivity and specificity. ROC curve analysis showed that the right eye stiffness value demonstrated high diagnostic accuracy for differentiating patients with ADHD from healthy controls, with an area under the curve (AUC) of 0.978 (95% CI: 0.954–1,000). Similarly, the left eye stiffness value showed excellent discriminatory ability, with an AUC of 0.971 (95% CI: 0.941–1,000). The mean bilateral eye stiffness value also demonstrated strong discriminative ability, with an AUC of 0.975 (95% CI: 0.947–1,000). In addition, a bilateral eye stiffness cutoff value of 10 kPa showed significant discriminatory performance, with an AUC of 0.919 (95% CI: 0.847–0.991) (Figure 4).

Using a bilateral eye stiffness cutoff value of 10 kPa, the sensitivity, specificity, positive predictive value, and negative

Table 1. Demographic Characteristics and Optic Nerve Measurements of the Study Groups

Parameters		Control Group (n:37)		ADHD Group (n:37)		p
		Mean ± SD/n-%	Median	Mean ± SD/n-%	Median	
Age		9.59 ± 2.63	9.00	9.95 ± 2.76	9.00	0.577 [m]
Gender	Female	17 45.9%		10 27.0%		0.091 [X²]
	Male	20 54.1%		27 73.0%		
ONSD(mm)						
Right		2.92 ± 0.23	2.90	2.92 ± 0.29	2.90	0.952 [m]
Left		2.96 ± 0.29	2.90	2.98 ± 0.25	2.90	0.864 [t]
SWE(kPa)						
Right		5.70 ± 3.02	4.41	25.31 ± 13.37	21.98	***0.000*** [m]
Left		5.63 ± 2.73	5.12	24.84 ± 13.79	27.03	***0.000*** [m]
Total Mean Stiffness		5.55 ± 2.54	4.93	25.27 ± 12.80	26.06	***0.000*** [m]

[t]: Independent Samples t-test / [m]: Mann-Whitney *U* test / [X²]: Chi-square test. $p < 0.050$ is considered statistically significant. ADHD: Attention Deficit Hyperactivity Disorder. ONSD: Optic Nerve Sheath Diameter. SWE: Shear Wave Elastograhy.

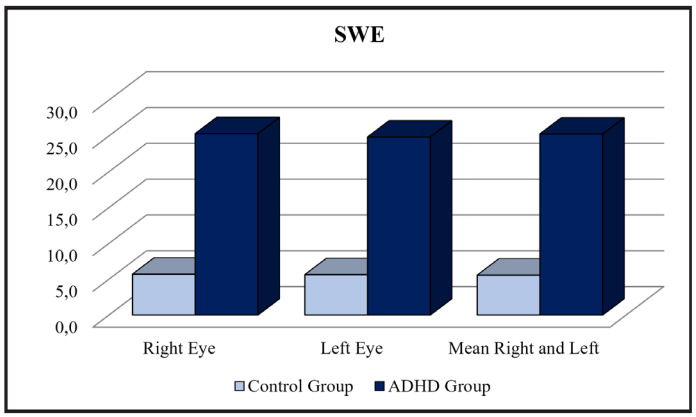

Figure 3. Comparison of mean bilateral optic nerve stiffness values between the ADHD and control groups.

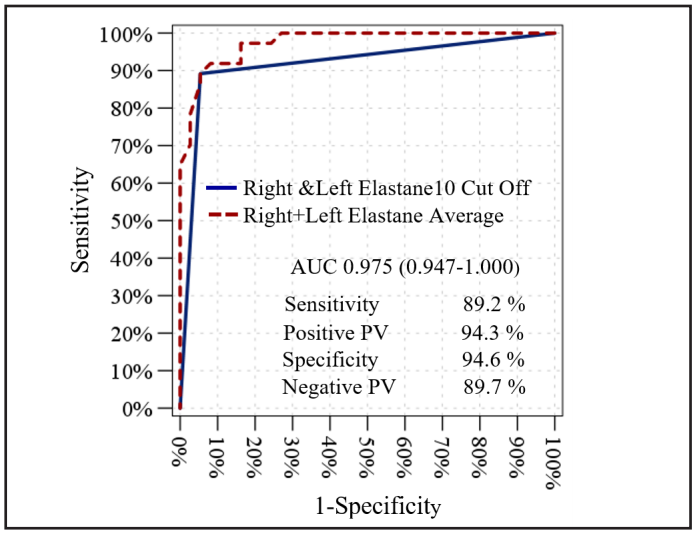

Figure 4. ROC curve analysis. The solid red line represents Right, and Left Eye Average Stiffness, the solid dark blue line represents Right and Left Eye Average Stiffness 10 Cut Off.

predictive value for distinguishing patients with ADHD from healthy controls were 89.2%, 94.6%, 94.3%, and 89.7%, respectively (Figure 4). The main between-group comparisons demonstrated large effect sizes, with Hedges' g values of 2.002 for right eye stiffness, 1.913 for left eye stiffness, and 2,114 for mean bilateral eye stiffness.

DISCUSSION

This prospective case-control study is the first in the literature to evaluate the biomechanical properties and stiffness of the optic nerve in children with ADHD using SWE. Our findings revealed a significant increase in optic nerve stiffness in children with ADHD compared with healthy control group. In contrast, morphometric parameters such as ONSD did not differ between groups. Furthermore, ROC curve analysis demonstrated high discriminatory performance for optic nerve elasticity measurements in this study sample, suggesting that SWE may have potential as an imaging biomarker for the evaluation of ADHD-related neurobiological alterations.

In recent years, ADHD research has expanded from focusing on macrostructural brain volumes to focusing on microstructural and neurovascular changes. Previous neuroimaging studies have shown volumetric changes in the prefrontal cortex, basal ganglia, gray matter, and white matter in children with ADHD [15–17]. Diffusion tensor imaging studies, in particular, have demonstrated impaired integrity of white matter tracts, including reduced fractional anisotropy in several neural pathways associated with attention and executive functioning [18]. Since the optic nerve is embryologically and anatomically considered a direct extension of the CNS, it is plausible that similar microstructural alterations may also affect optic nerve tissue in ADHD patients. Recent ophthalmologic imaging studies further support the presence of retinal and optic pathway alterations in ADHD [19]. Miquel-Lopez et al. [20]. demonstrated significant retinal thinning in children with ADHD using spectral-domain optical coherence tomography (SD-OCT), particularly affecting the retinal nerve fiber layer and macular structures. These findings suggest that ADHD-related neurodevelopmental abnormalities may extend beyond cortical and subcortical brain regions to involve retinal and optic nerve tissues as well. The increased optic nerve stiffness observed in our study may therefore represent another manifestation of these neurostructural alterations within the visual pathway. While OCT primarily evaluates structural retinal thinning, SWE provides complementary information regarding the biomechanical properties of optic nerve tissue. Together, these findings strengthen the hypothesis that the visual system may serve as a potential biomarker window for neurodevelopmental changes associated with ADHD.

A crucial finding of our study is that while tissue stiffness was significantly elevated in the ADHD group, conventional ONSD parameters showed no statistically significant difference between the cohorts. This discrepancy highlights that SWE provides a quantitative assessment of tissue biomechanical properties, whereas B-mode morphometry only captures macroscopic structural changes. Increased stiffness is generally associated with inflammation, gliosis, fibrosis, microvascular alterations, or structural remodeling within tissues. In recent years, SWE has emerged as a valuable imaging method in the evaluation

of orbital and optic nerve pathologies. Many studies have shown an increase in optic nerve stiffness in inflammatory and neurodegenerative conditions—for example, Yılmaz et al. [21]. significantly increased optic nerve stiffness has been reported in patients with Behçet's disease, suggesting subclinical neural involvement even in the absence of overt ophthalmological findings. Similarly, changes in optic nerve elasticity have been identified in glaucoma and diabetic retinopathy, characterized by neurovascular and microstructural degeneration [22,23].

Our findings suggest that neurodevelopmental differences associated with ADHD may manifest as increased optic nerve tissue stiffness in the absence of detectable morphometric changes in optic nerve diameter. Several hypotheses exist that could explain the significantly increased optic nerve stiffness observed in children with ADHD. First, chronic neuroinflammatory processes increasingly play a role in the pathophysiology of ADHD. High levels of inflammatory cytokines and immune dysregulation have been reported in some ADHD patients, and this may contribute to fine nerve tissue remodeling [24]. Second, abnormalities in myelination and axonal organization, previously demonstrated in white matter studies related to ADHD, may alter the biomechanical properties of the optic nerve tissue [25,26]. Third, chronic changes in dopaminergic and noradrenergic pathways, which underlie the pathophysiology of ADHD, may also affect regional microvascular tone and tissue perfusion, indirectly contributing to changes in the biomechanical properties of nerve tissues [27]. However, these mechanisms were not directly assessed in the present study and therefore should be considered hypotheses rather than demonstrated explanations for the observed SWE findings. Further studies incorporating structural, molecular, or histopathological assessments are required to determine the biological basis of the increased optic nerve stiffness observed in children with ADHD.

Although optic nerve shear wave elastography is a promising non-invasive technique for quantitative assessment of optic nerve tissue stiffness, its routine clinical applicability remains limited. The technique has not yet been widely implemented in clinical practice, partly because of variations in acquisition and measurement protocols, the lack of universally accepted reference values, and differences among ultrasound systems and transducer settings. Further studies with a standardised methodology, larger and more diverse patient populations, and multicentre validation are required to establish reliable reference ranges and determine the reproducibility and clinical utility of optic nerve SWE. Nevertheless, as a rapid and non-invasive imaging technique, optic nerve SWE may have potential for future clinical translation and could complement conventional ophthalmic and neuroimaging assessments once methodological and technical standardization is achieved.

Limitations

Our study has several limitations. First, the sample size is relatively small, which may limit the generalizability of the findings. Second, it is a single-center study. Third, correlation analysis was not performed between SWE findings and ADHD severity, symptom subtypes, disease duration, or treatment status. Fourth, although all examinations were performed by a single experienced radiologist to minimize interobserver variability, repeated measurements were not performed; therefore, intraobserver reliability and measurement reproducibility could not be assessed. Finally, it should be considered that ROC analysis may appear to have high diagnostic performance due to the relatively small sample size and case-control design In order to the clinical utility of optic nerve SWE as a potential biomarker for ADHD, further research is required in the form of external validation in larger, prospective, and independent cohorts. Moreover, advanced neuroimaging methodologies such as diffusion tensor imaging or optical coherence tomography were not included in the comparative evaluation. Future multicenter studies with larger patient populations and multimodal imaging approaches are needed to confirm these findings and elucidate the underlying pathophysiological mechanisms.

CONCLUSION

In conclusion, our study demonstrates that children with ADHD have significantly higher optic nerve stiffness compared to healthy individuals, and that SWE may provide a non-invasive approach for detecting differences in the biomechanical properties of the optic nerve in children with ADHD. SWE may represent a potential non-invasive imaging method for investigating nerve tissue changes in ADHD and may contribute to the development of novel imaging biomarkers in neurodevelopmental disorders.

Funding: This research received no external funding.

Informed Consent: Written informed consent was obtained from the parents of all participating children before any procedures were performed.

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Ethical Approval: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Clinical Research Ethics Committee of Kahramanmaraş Sütçü İmam University Faculty of Medicine (Approval number: 2023/10-07, Date: September 20, 2023).

Author Contributions: Conception: S.N.K.; S.C.A. - Design: S.N.K.; S.C.A. - Supervision: S.N.K.;S.C.A - Materials: S.N.K.;S.C.A - Data Collection and/or Processing: S.N.K.;S.C.A. - Analysis and/or Interpretation: S.N.K.; S.C.A - Literature Review: S.N.K.; S.C.A - Writing: S.N.K.

Author Statement Regarding the Use of Artificial Intelligence-Enhanced Tools: Artificial intelligence-based tools were used exclusively for linguistic refinement, including improvements in grammar, clarity, and overall readability. No artificial intelligence systems were involved in the study design, data analysis, interpretation of results, or the generation of scientific content.

REFERENCES

[1] Rajaprakash M, Leppert ML (2022) Attention-Deficit/Hyperactivity Disorder. Pediatr Rev. 43(3):135–147. https://doi.org/10.1542/pir.2020-000612

[2] Dobrosavljevic M, Larsson H, Cortese S (2023) The diagnosis and treatment of attention deficit hyperactivity disorder (ADHD) in older adults. Expert Rev Neurother. 23(10):883–893. https://doi.org/10.1080/14737175.2023.2250913

[3] Firouzabadi FD, Ramezanpour S, Firouzabadi MD, Yousem IJ, Puts NAJ, Yousem DM (2022) Neuroimaging in Attention-Deficit/Hyperactivity Disorder: Recent Advances. AJR Am J Roentgenol. 218(2):321–332. https://doi.org/10.2214/ajr.21.26316

[4] Rocca M, Hickman S, Bö L, Agosta F, Miller D, Comi G, Filippi M (2005) Imaging the optic nerve in multiple sclerosis. Mult Scler. 11(5):537–541. https://doi.org/10.1191/1352458505ms1213oa

[5] Stevens RRF, Gommer ED, Aries MJH, Ertl M, Mess WH, Huberts W, Delhaas T (2021) Optic nerve sheath diameter assessment by neurosonology: A review of methodologic discrepancies. J Neuroimaging. 31(5):814–825. https://doi.org/10.1111/jon.12906

[6] Melo RH, Gioli-Pereira L, Machado FS, Robba C (2025) Optic Nerve Sheath Diameter Sonography for the Diagnosis of Increased Intracranial Pressure in Nontraumatic Neurocritically Ill Patients:a Diagnostic Accuracy Systematic Review and Meta-Analysis. Neurocrit Care. 43(2):659–670. https://doi.org/10.1007/s12028-025-02249-6

[7] Aybar MD, Turna O. (2021) Shear wave elastography in optic neuritis: diagnostic accuracy of the optic nerve and adjacent fat tissue values. J Ultrason. 21(86):194–199. https://doi.org/10.15557/JoU.2021.0031

[8] Nitta N, Yamakawa M, Hachiya H, Shiina T (2021) A review of physical and engineering factors potentially affecting shear wave elastography. J Med Ultrason. 48(4):403–414. https://doi.org/10.1007/s10396-021-01127-w

[9] Lai C, Sun Y, Wang J, Purvin VA, He Y, Yang Q, Jing Y, Yin H, Zhu J. (2015) Optic perineuritis in Behçet disease. J Neuroophthalmol. 35(4):342–347. https://doi.org/10.1097/WNO.0000000000000264

[10] DeMill DL, Hussain M, Pop-Busui R, Shtein RM (2016) Ocular surface disease in patients with diabetic peripheral neuropathy. Br J Ophthalmol. 100(7):924–928. https://doi.org/10.1136/bjophthalmol-2015-307369

[11] Waisberg E, Micieli JA (2021) Neuro-Ophthalmological Optic Nerve Cupping:An Overview. Eye Brain. 13:255–68. https://doi.org/10.2147/eb.s272343

[12] Reimann GE, Jeong HJ, Durham EL, Archer C, Moore TM, Berhe F, Dupont RM, Kaczkurkin AN (2024) Gray matter volume associations in youth with ADHD features of inattention and hyperactivity/impulsivity. Hum Brain Mapp. 45(5):26589. https://doi.org/10.1002/hbm.26589

[13] Nárai Á, Hermann P, Rádosi A, Vakli P, Weiss B, Réthelyi JM, Bunford N, Vidnyánszky Z (2024) Amygdala Volume is Associated with ADHD Risk and Severity Beyond Comorbidities in Adolescents: Clinical Testing of Brain Chart Reference Standards. Res Child Adolesc Psychopathol. 52(7):1063–1074. https://doi.org/10.1007/s10802-024-01190-0

[14] Ünal F, Öktem F, Çetin Çuhadaroğlu F, Çengel Kültür SE, Akdemir D, Foto Özdemir D, Çak HT, Ünal D, Tıraş K, Aslan C, Kalaycı BM, Aydos BS, Kütük F, Taşyürek E, Karaokur R, Karabucak B, Karakök B, Karaer Y, Artık A (2019) Reliability and Validity of the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version, DSM-5 November 2016-Turkish Adaptation (K-SADS-PL-DSM-5-T)]. Turk Psikiyatri Derg. 30(1):42–50.

[15] Singh M, Skippen P, He J, Thomson P, Fuelscher I, Caeyenberghs K, Anderson V, Hyde C, Silk TJ (2024) Developmental patterns of inhibition and fronto-basal-ganglia white matter organisation in healthy children and children with attention-deficit/hyperactivity disorder. Hum Brain Mapp. 45(15):70010. https://doi.org/10.1002/hbm.70010

[16] Shvarzman R, Crocetti D, Rosch KS, Li X, Mostofsky SH (2022) Reduced basal ganglia tissue-iron concentration in school-age children with attention-deficit/hyperactivity disorder is localized to limbic circuitry. Exp Brain Res. 240(12):3271–3288. https://doi.org/10.1007/s00221-022-06484-7

[17] Li CS, Chen Y, Ide JS (2022) Gray matter volumetric correlates of attention deficit and hyperactivity traits in emerging adolescents. Sci Rep. 12(1):11367. https://doi.org/10.1038/s41598-022-15124-7

[18] Dramsdahl M, Westerhausen R, Haavik J, Hugdahl K, Plessen KJ (2012) Adults with attention-deficit/hyperactivity disorder—a diffusion-tensor imaging study of the corpus callosum. Psychiatry Res Neuroimaging. 201(2):168–173. https://doi.org/10.1016/j.pscychresns.2011.08.005

[19] Li SL, Kam KW, Chee ASH, Zhang XJ, Chen LJ, Yip WWK, Tham CC, Young AL, Wong ICK, Ip P, Yam JC (2021) The association between attention-deficit/hyperactivity disorder and retinal nerve fiber/ganglion cell layer thickness measured by optical coherence tomography: a systematic review and meta-analysis. Int Ophthalmol. 41(9):3211–3221. https://doi.org/10.1007/s10792-021-01852-8

[20] Miquel-Lopez C, Garcia-Medina JJ, Lopez-Hernandez AE, Garcia-Ayuso D, De-Paco-Matallana M, Hernandez-Olivares J, Pinazo-Duran MD, Del-Rio-Vellosillo M (2025) Retinal Thinning in Attention Deficit Hyperactivity Disorder (ADHD): Structural Changes Detected by Spectral-Domain OCT. J Clin Med. 14(16):5723. https://doi.org/10.3390/jcm14165723

[21] Yilmaz BK, Ozdemir S, Diracoglu A, Selcuk Can T, Turkay R (2022) Utilizing shear wave elastography for the evaluation of optical nerve involvement in Behçet's disease. Photodiagnosis Photodyn Ther. 40:103096. https://doi.org/10.1016/j.pdpdt.2022.103096

[22] Bui NT, Kazemi A, Chen JJ, Larson NB, Sit AJ, Zhang X (2025) Analysis wave speed of optic nerve and optic nerve head for assessing normal tension glaucoma by using vibro-elastography technique. Clin Biomech (Bristol). 124:106493. https://doi.org/10.1016/j.clinbiomech.2025.106493

[23] Yue C, Cai-Hong W (2024) Study of the optic nerve in patients with type 2 diabetic retinopathy by shear-wave elastography. Clin Radiol. 79(4):574–581. https://doi.org/10.1016/j.crad.2023.12.019

[24] Anand D, Colpo GD, Zeni G, Zeni CP, Teixeira AL (2017) Attention-Deficit/Hyperactivity Disorder And Inflammation: What Does Current Knowledge Tell Us? A Systematic Review. Front Psychiatry. 8:228. https://doi.org/10.3389/fpsyt.2017.00228

[25] Nagel BJ, Bathula D, Herting M, Schmitt C, Kroenke CD, Fair D, Nigg JT (2011) Altered white matter microstructure in children with attention-deficit/hyperactivity disorder. J Am Acad Child Adolesc Psychiatry. 50(3):283–292. https://doi.org/10.1016/j.jaac.2010.12.003

[26] Dunn GA, Nigg JT, Sullivan EL (2019) Neuroinflammation as a risk factor for attention deficit hyperactivity disorder. Pharmacol Biochem Behav. 182:22–34. https://doi.org/10.1016/j.pbb.2019.05.005

[27] MacDonald HJ, Kleppe R, Szigetvari PD, Haavik J (2024) The dopamine hypothesis for ADHD: An evaluation of evidence accumulated from human studies and animal models. Front Psychiatry. 15:1492126. https://doi.org/10.3389/fpsyt.2024.1492126

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