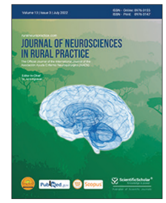
https://ruralneuropractice.com

ScientificScholar® Knowledge is power
Publisher of Scientific Journals

Journal of Neurosciences in Rural Practice



Original Article

Sensory processing abilities and their impact on disease severity in children with attention-deficit hyperactivity disorder

Prateek Kumar Panda[1], Aparna Ramachandran[2], Vinod Kumar[1], Indar Kumar Sharawat[1]

[1]Division of Pediatric Neurology, Department of Pediatrics, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, [2]Department of Neurology, IQRAA International Hospital and Research Centre, Kozhikode, Kerala, India.

ABSTRACT

Objectives: Although several studies have shown sensory processing abnormalities in pediatric subjects with attention-deficit hyperactivity disorder (ADHD), there is significant heterogeneity among their results.

Materials and Methods: This study was performed to compare the sensory processing abilities of children and adolescents with and without ADHD aged 6–15 years and to correlate the sensory processing problems in these patients, with the symptom profile and severity of ADHD. While child sensory profile-2 (SP-2) was used to assess, the sensory processing abilities of ADHD patients, revised Connor's parent rating scale revised, Malin's intelligence scale for Indian children, grade level assessment device, and child behavior checklist were used to assess ADHD symptom severity, intelligence, learning, and behavioral problems, respectively.

Results: A total of 66 ADHD patients enrolled (60 boys), 22 (28%), 7 (9%), and 49 (63%) cases were the ADHD-hyperactive-impulsive (ADHD-HI), ADHD-inattentive, and ADHD-combined (ADHD-C) types, respectively, and 33 typically developing controls. The ADHD patients had a significantly low raw score on most of the factors, sections, and response patterns of SP-2 ($P < 0.05$), but only four and one ADHD patients had auditory and visual processing scores outside the normal clinical range. There was a trend toward higher scores in the children with ADHD-C and ADHD-HI subtypes. There was a moderate negative correlation between hyperactivity/impulsivity T-score and auditory processing scores in the SP ($P < 0.05$, $r = -0.43$). We observed a negative correlation, although weak, between visual processing scores and hyperactivity/impulsivity and a positive correlation between the severity of conduct disorder-related problems, oppositional defiant problems, anxiety problems, and auditory as well as tactile processing scores ($P < 0.05$). In the quadrant score summary, the scores for all four types, that is, sensory sensitivity, low registration, sensation avoiding, and sensation seeking, were significantly more in the ADHD group, as compared to healthy controls.

Conclusion: Sensory processing abilities in ADHD children differ from that of typically developing children when objectively assessed, although most of the ADHD children had scores in the clinically normal range. The sensory processing profile also has an impact on the severity and comorbidity profile of ADHD patients.

Keywords: Behavioral disorders, Neurodevelopmental disorder, Attention-deficit/hyperactivity disorder, Hyperactivity, Sensory processing abnormalities

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder, which is as common as affecting around 7% of school-age children.[1,2] The diagnostic criteria described in the Fifth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) are commonly used to diagnose ADHD and divide ADHD patients into three subtypes: Predominantly inattentive subtype (ADHD-I), predominantly hyperactive-impulsive (ADHD-HI), and combined subtype (ADHD-C).[3] Apart from the core symptoms of impulsivity, hyperactivity, and inattention, ADHD patients often show several comorbidities such as conduct disorder (CD), oppositional defiant disorder (ODD), sleep disturbances, tics, learning disability, anxiety, and depression.[4] However, sensory processing abnormalities are not considered either as a core feature or commonly associated with the comorbidity of these disorders.[5] A few studies in the past two decades have explored the sensory processing abilities of ADHD patients from various parts of the world.[6-8] Most of the completed studies showed at least some clinically/subclinically detectable hyporesponsivity/hyperresponsivity to auditory, visual, and tactile stimuli.[9,10] Second, previous studies have also shown that these sensory processing issues also affect the symptom profile and

***Corresponding author:** Indar Kumar Sharawat, Division of Pediatric Neurology, Department of Pediatrics, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India. sherawatdrindar@gmail.com

Received: 08 January 2023 **Accepted:** 10 July 2023 **Published:** 16 August 2023 **DOI**: 10.25259/JNRP_22_2023

severity of ADHD.[11,12] However, the systematic review by Ghanizadeh.[5] could not reach at a definite conclusion due to the several methodological limitations and the small sample size of many included studies. We have planned to compare the sensory processing problems of ADHD patients with typically developing children using a standardized validated measure like sensory profile-2 (SP-2) and will evaluate for determinants and impact of sensory processing problems in these patients.

MATERIALS AND METHODS

This was a cross-sectional study conducted in a tertiary care hospital and associated medical college in North India between August 2019 and November 2022. The primary objective of this study was to compare the sensory responses of children and adolescents with and without ADHD aged 6–15 years. The secondary objectives were to describe the neurobehavioral profile and psychiatric and other comorbidities of ADHD patients and to correlate the sensory processing problems in these patients, with the symptom profile and severity of ADHD.

In the study by Shimizu *et al.*,[13] a moderate effect size was observed for the difference in sensory responses of children with and without ADHD. Hence, we assumed the effect size for the difference in sensory responses between the two groups to be 0.5. With a presumed, power of 80%, alpha error of 0.05, and an allocation ratio of 2:1 in ADHD and control group, we calculated a sample size of 66 in ADHD group and 33 in the control group.

We included patients aged 6–15 years with ADHD satisfying DSM-V criteria for the same (ADHD-HI, ADHD-I, and ADHD-C subtypes), in the ADHD group. We attempted to include all consecutive children and adolescents satisfying the inclusion criteria to be included in the study, to avoid sampling bias, irrespective of the duration of illness, previous medications or behavioral therapy, or comorbidities. The participants in the control group were matched to the participants in the ADHD group, for three main sociodemographic variables (gender, age, and socioeconomic status [SES]) and without any major systemic illness. For matching, we started with a number "1" and then every alternative participant from the first participant in the ADHD group was matched for age, gender, and SES, to ensure a 2:1 enrolment ratio, without any bias.

After obtaining Institutional Ethics Committee approval and informed written consent from the caregivers, the participants were subjected to detailed clinical and neuropsychological examination, apart from noting their sociodemographic details. In clinical variables, we included any abnormalities on physical examination or neurological examination, previous history of seizure or other neurological problems, and any comorbid illnesses such as CD, ODD, sleep problems, specific learning disability (SLD), substance abuse, epilepsy, and autistic features. We also noted their recent most academic grades and whether they were studying to age-appropriate standards in school/in the past required multiple attempts to pass a particular standard.

The neuropsychological assessment included the following: ADHD symptoms severity was rated by the revised Connor's Parent Rating Scale-Revised (CPRS-R), intellectual level of the participant was tested using the Malin's Intelligence Scale for Indian Children, presence, and severity of SLD were assessed by Grade Level Assessment Device and National Institute of Mental Health and NeuroSciences SLD battery. The attention was specifically assessed by the Continuous Performance Test, working memory was assessed by the forward and backward digit span test and Corsi Block-Tapping test, and executive function by the Behavior Rating Inventory of Executive Functions (BRIEF) test.[14-16] Other comorbidities were initially screened with the Child Behavior Checklist, and subsequently, their diagnosis was confirmed with DSM-V criteria for individual disorders. The severity of comorbid ODD and CD were measured by the ODD Rating scale (ODDRS) and CD Rating Scale-for parents (CDRS-P), respectively, whereas comorbid depression severity was measured by CDRS.[17,18]

Children in whom ADHD symptoms were not the primary concern and they were suffering mainly from other pervasive developmental disorders such as autism spectrum disorder or psychiatric disorders such as bipolar disorders, major depressive disorder, schizophrenia neurological disorders (e.g., cerebral palsy, epileptic encephalopathy, neurodegenerative disorder, and non-traumatic and traumatic brain injury), and intellectual disability (intelligence quotient <70) were excluded from the study.

Child SP-2 was used for assessing sensory processing abilities. It is answered by a parent or caregiver and the questions are designed to measure the behavioral responses of children to daily sensory events. It can detect both under-responsivity corresponding to a high neurological threshold and over-responsivity corresponding to a low neurological threshold.[19]

This scale has 86 items, which are arranged into 14 sections, 4 response patterns, and 9 factors. Sensory processing, modulation, and behavioral and emotional responses are three categories, into which these 14 sections are divided into. Combined scores from different sections lead to 9 factors. The combined scores from these factors determine the four response patterns. A higher score indicates a lower frequency of undesirable behavioral responses to sensory stimuli. Separate investigators performed SP-2 and the rest of the other neuropsychological assessments, unaware of the findings of each other to avoid bias.[20]

Statistical analysis

Data were initially entered in a predesigned structured pro forma and then transferred to a Microsoft Excel spreadsheet. We performed requisite statistical tests using the Statistical Package for the Social Sciences software version 29.0. Continuous variables such as age and score of a particular domain of SP were presented either with median/interquartile range or mean ± standard deviation, depending on whether the variable followed normal distribution or not. We used the student's *t*-test or Wilcoxon rank-sum test to compare the distribution of continuous variables like scores of individual domains and ADHD severity scores among the two groups for statistical significance. We described the categorical variables by utilizing frequency (in percentage) and a 95% confidence interval. We checked the distribution of these categorical variables such as gender distribution for significant difference between the two groups using Fisher's exact test. The correlation between the two variables was tested using Pearson's or Spearman's correlation coefficient. We considered $P < 0.05$ to be statistically significant.

RESULTS

Out of the 66 ADHD patients enrolled (60 boys, 90%, 10.7 ± 1.9 years), 5, 19, and 42 cases were of the ADHD-I, ADHD-HI, and ADHD-C types, respectively, according to DSM-V criteria. Fifty-four (83%) cases had at least one or more ADHD-associated comorbidity. SLD (*n* = 31, 46%), ODD (*n* = 37, 55%), CD (*n* = 22, 34%), anxiety (*n* = 17, 27%), depression (*n* = 9, 13%), somatic symptoms (*n* = 25, 39%), sleep problems (*n* = 23, 35%), motor/vocal tics (*n* = 16, 25%), and obsessive compulsion disorder (*n* = 5, 8%) were various comorbidities reported in our cohort. As high as 63 (96%) of participants were receiving at least one medication for ADHD, as in our center, we routinely prescribe both behavioral intervention and medications simultaneously, unless medications are not required clinically or contraindicated. While 34 (51%) participants were receiving atomoxetine alone, 22 (33%) and 2 (3%) children were receiving methylphenidate and clonidine. Rest, 5 (7.5%) children were receiving both methylphenidate and atomoxetine. The baseline demographic and clinical characteristics of the ADHD group and age, gender, and SES are shown in [Table 1].

Table 1: Clinical and sociodemographic variables in ADHD and control groups.

Characteristics	ADHD group (*n*=66)	Control group (*n*=33)	*P*-value
Type of ADHD			
ADHD-I	5	0	<0.0001
ADHD-HI	17	0	
ADHD-C	44	0	
Gender			
Male	60	30	1.0
Female	6	3	
Age	10.7±1.9	10.8±1.6	0.94
Residence			
Rural	56	45	0.92
Urban	10	11	
Socioeconomic status			
Upper	2	1	0.86
Middle	33	17	
Lower	31	15	
Schooling			
Public schooling	45	22	0.90
Private schooling	21	11	
Comorbidities			
SLD	31	0	<0.001
ODD	37	0	
CD	22	0	
Anxiety	17	0	
Depression	9	0	
Somatic symptoms	25	0	
OCD	5	0	0.23
Epilepsy	0	0	-
Sleep problems (CSHQ>41)	23	0	<0.01
Tics (motor or vocal)	16	0	<0.01
IQ	90.1±3.5	94.3±2.1	0.45

OCD: Obsessive compulsion disorder, ADHD: Attention-deficit hyperactivity disorder, ADHD-I: ADHD inattentive, ADHD-HI: ADHD-hyperactive-impulsive, ADHD-C: ADHD-combined, SLD: Specific learning disability, ODD: Oppositional defiant disorder, CD: Conduct disorder, IQ: Intelligence quotient

The ADHD group had a significantly low raw score on most of the factors, sections, and response patterns of the SP-2 [Table 2]. The effect size for the difference between the two groups was moderate or large for ten out of 14 sections of the SP. However, none of the participants in either group had values suggesting that they are much more or much less likely as compared to the others in the general population. However, in the ADHD group, four and two participants had auditory and visual processing scores in the range suggesting that they are more likely to have auditory and visual processing problems compared to the majority of others, in contrast to the typically developing control group, who had scored for individual sections in the range, which suggested that they are behaving like the majority of others in the general population. Furthermore, the difference between the proportion of participants in ADHD and control groups who had scores for individual sections in the clinically abnormal range was not statistically significant ($P > 0.05$, for all).

When we compared the scores on various SP-2 subsections between three sub-types of ADHD, there were no significant differences between them, although there was a trend toward the higher score in the children with ADHD-HI and ADHD-C subtypes. It suggests that patients with the

Table 2: Comparison of sensory profile scores between the *ADHD* group and control group.

Sensory profile score	ADHD group (*n*=66)	Control group (*n*=33)	*P*-value
Sections			
Auditory processing	31.4±6.2	20.7±5.4	<0.01
Visual processing	39.7±5.7	32.1±6.1	<0.01
Vestibular processing	44.3±5.2	36.3±4.6	<0.01
Touch processing	78.9±7.3	65.8±8.5	0.03
Multisensory processing	31.8±5.2	23.5±4.1	0.02
Oral processing	47.5±6.7	36.8±5.1	<0.01
Sensory modulations			
Sensory processing related to endurance/tone	43.6±5.8	35.2±4.7	<0.01
Modulation related to body position and movement	40.2±5.7	31.2±4.8	<0.01
Modulation of movement affecting activity level	21.6±4.8	15.4±3.9	<0.01
Modulation of sensory input affecting emotional responses	15.3±3.7	10.1±2.8	0.02
Modulation of visual input affecting emotion/activity level	10.4±2.7	7.3±1.8	<0.01
Behavioral and emotional responses			
Emotional/social response	67.4±10.5	53.2±11.6	<0.01
Behavior outcomes sensory processing	24.3±4.2	16.8±3.3	<0.01
Items indicating thresholds for response	13.5±2.9	8.4±2.7	<0.01

ADHD: Attention-deficit hyperactivity disorder

ADHD-I subtype tend to be hyporesponsive, whereas those with ADHD-HI and ADHD-C subtypes tend to be hyperresponsive. Corresponding to this, the proportion of participants whose score in any of the subsections of SP-2 was much less than others (<3rd centile) was numerically more in the ADHD-I group and the proportion of participants whose score in any of the subsections of SP-2 was much more than majority others (>97th centile) was numerically more in ADHD-I group. However, this difference was not statistically significant, suggesting the majority of ADHD patients had SP-2 subsection scores between the 3rd and 97th centile (i.e., "either less than others," "just like the majority of others" or "more than the majority of others"). The difference between ADHD subtypes was numerically more discriminative for auditory processing scores; still, the difference was not statistically significant.

There was a moderate negative correlation between hyperactivity/impulsivity T-score and auditory processing scores in SP-2 ($P < 0.05$, r = −0.43). It suggests that ADHD patients with more hyperactivity/impulsivity have more auditory processing problems. There was a weak negative correlation between visual processing score and hyperactivity/impulsivity T-score in CPRS-R, but a moderate negative correlation between visual processing score and learning problems T-score in CPRS-R. It suggests that probably due to underlying inattention or other inherent problems of ADHD, these patients suffer from learning issues, which could be related to slow and imperfect processing of visual stimuli. For vestibular processing, touch processing, and oral processing, no significant correlation was observed with the severity of ADHD symptoms in CPRS-R [Table 3]. It suggests although all sections of SP-2 are more significantly affected as compared to healthy controls, auditory and visual processing are more affected.

However, for the patients with ADHD-C type, there was a trend toward higher scores for vestibular processing, as compared to their counterparts, but it did not reach the point of statistical significance ($P = 0.09$). It suggests that, at least, a subset of ADHD patients have problems with balance and coordination. The inattention-related T-score in CPRS-R had a weak negative correlation with vestibular processing, suggesting inattention problems might be related to poor processing of balance and coordination-related issues in ADHD children. The forward digit span score and Corsi block span test score showed a moderate negative correlation with auditory and visual processing scores (r = −0.4–−0.6, reaffirming the previous findings. Both these findings suggest that inattention in ADHD patients might be related to poor auditory and visual processing or it might be because inattention in these children leads to poor auditory and visual processing.

There was a weak yet significant positive correlation between the severity of CD-related problems in CDRS-P, oppositional defiant problems in ODDRS, and anxiety problems in Screen for Child Anxiety-Related Disorders and auditory as well as tactile processing scores in SP-2 ($P < 0.05$, r−0.2–0.4). It suggests that ADHD patients with anxiety and more severe conduct/oppositional defiant problems tend to be hyperresponsive to sensory stimuli. The emotional-social response section score in the SP-2 score had a moderate positive correlation with anxiety and depression severity (r = 0.47 and 0.52, respectively). The executive function measured by BRIEF was lower

Table 3: Comparison of various clinical severity scales between ADHD and control group.

Variable	ADHD group (*n*=66)	Control group (*n*=33)	*P*-value
Connor's parent rating scale (value in T-scores)			
Hyperactivity/Impulsivity	74.5±11.2	24.5±5.7	<0.0001
Executive functioning	73.6±10.5	23.7±6.1	
Learning problems	72.9±11.2	24.8±5.9	
Aggression	74.5±13.1	22.9±5.3	
Peer relations	72.8±10.6	24.1±5.6	
Inattention	71.7±11.2	23.8±6.1	
DSM-V symptom scales			
ADHD predominantly inattentive presentation	71.8±10.8	23.6±5.8	<0.0001
ADHD predominantly hyperactive-impulsive presentation	73.9±11.7	24.9±5.2	
Conduct disorder	72.8±10.1	24.5±6.4	
Oppositional defiant disorder	73.1±11.2	23.8±5.9	
CDRS-P	34.6±5.8	10.1±3.9	
ODDRS	14.2±3.9	3.7±0.2	
Forward digit span score	3.7±1.2	5.4±1.6	
Backward digit span score	2.6±0.5	4.7±1.4	
Block span in Corsi block tapping test	2.7±0.9	4.3±1.2	
BRIEF T-scores			
Behavioral regulation index	71.4±4.9	22.6±6.8	<0.0001
Metacognition index	67.8±3.5	24.9±7.2	
Global executive composite	69.3±4.2	23.6±6.8	
Childhood depression rating scale	23.6±7.4	10.2±4.8	

ADHD: Attention-deficit hyperactivity disorder, CDRS-P: Conduct disorder rating scale-for parents, ODDRS: Oppositional defiant disorder rating scale, DSM-5: Fifth Edition of the Diagnostic and Statistical Manual of Mental Disorders, BRIEF: Behavior rating inventory of executive functions

as compared to healthy controls. However, apart from a weak positive correlation between the Global executive composite T-score and the auditory processing score ($P < 0.05$, $r = 0.31$), no other significant correlation was observed for other sections. In the quadrant score summary, the scores for all four types, that is, low registration, sensory sensitivity, sensation seeking, and sensation avoiding were significantly higher in the ADHD group as compared to healthy controls. However, the number of patients who had scored "much more than others" was higher for "low registration" and "sensory sensitivity" patterns compared to healthy controls and not for the other two patterns. Finally, we could not detect any significant difference between various section scores of SP-2 between patients receiving different medications. Moreover, there was no significant impact of other demographic variables such as age, gender, and SES on SP-2 scores suggesting that the abnormalities noted in ADHD patients were inherent to the disease characteristics.

DISCUSSION

Our study explores sensory processing problems in an Indian cohort of ADHD and compared them with healthy, typically developing controls. Consistent with previous clinical studies, our study also showed that ADHD children have more sensory processing abnormalities. However, unlike autistic children, who had often sensory symptoms evident from history and SP scores largely outside the reference range, children and adolescents with ADHD have more subclinical sensory problems, detectable only by performing detailed, objective evaluation.[21] However, these sensory processing problems differ in extent and characteristics between ADHD subtypes. There was also a significant correlation between the severity of ADHD symptoms in some domains and the severity of some comorbid symptoms with sensory-processing abnormalities.

The finding in our study that sensory processing scores in most of the domains of SP-2 are different from the healthy controls has been shown in the study by Shimizu *et al*. from Brazil.[13] Dunn and Bennett.[22] also had similar findings and our cohort of ADHD patients resembles more to this cohort because the majority of children in this cohort were also receiving various medications like our cohort. Yochman *et al*.[9] also found a significant difference for 11 out of 14 sections, except for vestibular processing, emotional response, and tone/endurance. However, they mainly included pre-schoolers. ADHD and sensory processing problems often change with the increase in age and probably the reason behind some disparities between the results of this study and our study.

Although most studies concluded about the existence of sensory processing problems in ADHD children, its type, severity, and clinical correlation with symptom profile varied across studies. While most studies showed some problems in visual and auditory processing problems, few studies had previously assessed tactile, vestibular, and olfactory processing abilities. While the majority of studies showed sensory hyper-responsivity to various modalities, some studies also demonstrated sensory hyporesponsivity. However, not all ADHD patients follow the same pattern of sensory abnormalities. Even different children with autism show different types of sensory abnormalities. For this purpose, in our study, we also tried to find out how many children showed scores in individual sections beyond the 97th or 3rd centile (much more or much less than the majority of others). However, a previous systematic review in this regard by Ghanizadeh.[5] showed that ADHD patients with sensory hyper-responsivity showed more features of anxiety and oppositional defiant behavior. These findings have also been shown in our study, although the strength of the correlation was weak.

Parush *et al.*[23] have previously shown that tactile defensiveness or hyperresponsiveness to tactile stimuli was more common in females. Our study probably did not reach such a conclusion, as we had only a few female participants in our study or it might be due to ethnic differences between the sample population of both studies.

At least one-third of children with ADHD have been shown to have significant problems in balance, coordination, and equilibrium in a study by Sergeant *et al.*,[24] and they were found to suffer from developmental coordination disorder. Although few other studies have also shown problems with balance and coordination in children with ADHD, such high prevalence has not been shown in subsequent studies or our study.

Children with ADHD have been shown to have difficulty with auditory discrimination, auditory localization, both hyporesponsivity (under-registration of sound) and hyper-responsivity to sound.[5] While ADHD-I type patients showed auditory hyporesponsivity, the opposite was true for the ADHD-HI type. The same trend was also observed in our study, although it missed the level of statistical significance, probably due to the small number of patients in the ADHD-I subgroup. Ghanizadeh.[5] also have previously shown that patients with ADHD and co-occurring ODD are more likely to be hyporesponsive to auditory stimuli.

Stimulants have been suspected to induce visual hyperresponsivity or photophobia in a previous study by Ghanizadeh.[5] However, this finding is not substantiated in our study, although formal visual field assessment was not part of our study. Future studies need to objectively evaluate various types of vision abnormalities before and after the use of stimulants.

Although abnormalities in sensory processing in ADHD subjects are less substantial than in autistic children and none of these patterns of abnormalities described are highly specific to be used as a discriminatory or diagnostic modality, it probably has some therapeutic implications. At least, those subjects having SP-2 scores fairly out of the normal range should be advised appropriate sensory integration therapy. Certain psychiatric comorbidities are more common in patients with sensory hyperresponsivity and need to be addressed appropriately. Almost all studies on ADHD patients in this regard are cross-sectional studies and have not explored the therapeutic implications. Miller *et al.* have shown that even occupational therapy can help patients with sensory modulation disorder. Whether the same holds true for ADHD patients or not needs to be evaluated. Pharmacotherapy in ADHD and other disorders has been proposed to modulate and sometimes even alleviate sensory issues. The existing literature, however, did not show any definite advantage or disadvantage of stimulants or other medications on sensory issues in ADHD patients.

The parent report version of SP-2 is only a subjective measure and might have underestimated or overestimated the sensory issues. Almost all previous studies have also focused on parent-report questionnaires. Future studies exploring more objective measures and laboratory tests like evoked potentials are likely to provide a more accurate description of sensory issues in ADHD patients. Anokhin *et al.*[25] have proposed the possibility of putative genetic factors in the subclinical differences in evoked potentials in these patients. As these evoked responses are suspected to be somewhat different in ADHD patients as compared to the normal population, genetic polymorphism or mutation analysis in ADHD patients with significant sensory issues may provide yet unknown details of underlying genetic biomechanics.

Overall, our study is the first from the Indian subcontinent, which has systematically compared sensory issues in ADHD children and adolescents with healthy children and reaffirmed the findings in previous studies from other parts of the world. Due to several methodological limitations and heterogeneity of findings of various studies, it is difficult to reach a certain conclusion about a particular sensory abnormality pattern in ADHD patients.

CONCLUSION

Sensory processing abilities in ADHD children differ from that of typically developing children when objectively assessed, although most of the ADHD children had scores in the clinically normal range. The sensory processing profile also has an association with the severity and comorbidity profile of ADHD patients.

Declaration of patient consent

The authors certify that they have obtained all appropriate consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Hamed AM, Kauer AJ, Stevens HE. Why the diagnosis of attention deficit hyperactivity disorder matters. Front Psychiatry 2015;6:168.
2. Faraone SV, Asherson P, Banaschewski T, Biederman J, Buitelaar JK, Ramos-Quiroga JA, *et al*. Attention-deficit/hyperactivity disorder. Nat Rev Dis Primer 2015;1:15020.
3. Cabral MD, Liu S, Soares N. Attention-deficit/hyperactivity disorder: Diagnostic criteria, epidemiology, risk factors and evaluation in youth. Transl Pediatr 2020;9:S104-13.
4. Gnanavel S, Sharma P, Kaushal P, Hussain S. Attention deficit hyperactivity disorder and comorbidity: A review of literature. World J Clin Cases 2019;7:2420-6.
5. Ghanizadeh A. Sensory processing problems in children with ADHD, a systematic review. Psychiatry Investig 2011;8:89-94.
6. Ghanizadeh A. Parents reported oral sensory sensitivity processing and food preference in ADHD. J Psychiatr Ment Health Nurs 2013;20:426-32.
7. Pfeiffer B, Daly BP, Nicholls EG, Gullo DF. Assessing sensory processing problems in children with and without attention deficit hyperactivity disorder. Phys Occup Ther Pediatr 2015;35:1-12.
8. Koziol LF, Budding D. ADHD and sensory processing disorders: Placing the diagnostic issues in context. Appl Neuropsychol Child 2012;1:137-44.
9. Yochman A, Alon-Beery O, Sribman A, Parush S. Differential diagnosis of sensory modulation disorder (SMD) and attention deficit hyperactivity disorder (ADHD): Participation, sensation, and attention. Front Hum Neurosci 2013;7:862.
10. Bijlenga D, Tjon-Ka-Jie JY, Schuijers F, Kooij JJ. Atypical sensory profiles as core features of adult ADHD, irrespective of autistic symptoms. Eur Psychiatry 2017;43:51-7.
11. Karsz FR, Vance A, Anderson VA, Brann PG, Wood SJ, Pantelis C, *et al*. Olfactory impairments in child attention-deficit/hyperactivity disorder. J Clin Psychiatry 2008;69:1462-8.
12. Ghanizadeh A. Can behavioral sensory processing problems guide us to a better pharmacological management of children with attention deficit hyperactivity disorder?: A case report. Psychiatry (Edgmont) 2009;6:40-3.
13. Shimizu VT, Bueno OF, Miranda MC. Sensory processing abilities of children with ADHD. Braz J Phys Ther 2014;18:343-52.
14. Berch DB, Krikorian R, Huha EM. The Corsi block-tapping task: Methodological and theoretical considerations. Brain Cogn 1998;38:317-38.
15. McAuley T, Chen S, Goos L, Schachar R, Crosbie J. Is the behavior rating inventory of executive function more strongly associated with measures of impairment or executive function? J Int Neuropsychol Soc 2010;16:495-505.
16. Baker DB, Taylor CJ, Leyva C. Continuous performance tests: A comparison of modalities. J Clin Psychol 1995;51:548-51.
17. Waschbusch DA, Elgar FJ. Development and validation of the Conduct Disorder Rating Scale. Assessment 2007;14:65-74.
18. Ise E, Görtz-Dorten A, Döpfner M. Reliability and validity of teacher-rated symptoms of oppositional defiant disorder and conduct disorder in a clinical sample. Psychopathology 2014;47:312-8.
19. Simpson K, Adams D, Alston-Knox C, Heussler HS, Keen D. Exploring the sensory profiles of children on the autism spectrum using the short sensory profile-2 (SSP-2). J Autism Dev Disord 2019;49:2069-79.
20. Licciardi L, Brown T. An overview & critical review of the Sensory Profile - second edition. Scand J Occup Ther 2023;30:758-70.
21. Posar A, Visconti P. Sensory abnormalities in children with autism spectrum disorder. J Pediatr (Rio J) 2018;94:342-50.
22. Dunn W, Bennett D. Patterns of sensory processing in children with attention deficit hyperactivity disorder. OTJR Occup Participation Health 2002;22:4-15.
23. Parush S, Sohmer H, Steinberg A, Kaitz M. Somatosensory function in boys with ADHD and tactile defensiveness. Physiol Behav 2007;90:553-8.
24. Sergeant JA, Piek JP, Oosterlaan J. ADHD and DCD: A relationship in need of research. Hum Mov Sci 2006;25:76-89.
25. Anokhin AP, Vedeniapin AB, Heath AC, Korzyukov O, Boutros NN. Genetic and environmental influences on sensory gating of mid-latency auditory evoked responses: A twin study. Schizophr Res 2007;89:312-9.

How to cite this article: Panda PK, Ramachandran A, Kumar V, Sharawat IK. Sensory processing abilities and their impact on disease severity in children with attention-deficit hyperactivity disorder. J Neurosci Rural Pract 2023;14:509-15.