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ORIGINAL ARTICLE

Comparison of ADOS-2 scores in adults with attention deficit hyperactivity disorder and autism spectrum disorder

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Abstract

Aim: Attention deficit hyperactivity disorder (ADHD) symptoms persist significantly into adulthood; however, only a few studies have examined the overlap between ADHD and autism spectrum disorder (ASD) symptoms in adults. This study compared ASD symptoms in adults with ASD, ADHD, and neurotypical controls using the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2).

Methods: In total, 150 adults (69 with ADHD [mean age, 34.5 years; 43 men], 50 with ASD [mean age, 33.8 years; 35 men], and 31 controls [mean age, 38.7 years; 17 men]) completed Module 4 of the ADOS-2, the Autism Spectrum Quotient, Conners' Adult ADHD Rating Scale, and the Wechsler Adult Intelligence Scale.

Results: Consistent with juvenile studies, adults with ADHD exhibited significant ASD symptoms, which were between those with ASD and neurotypical individuals. Item-level analysis suggested more similarities than differences between the two disorders; the differences may be of degree rather than quality.

Conclusion: This study shows the importance of assessing full ASD symptoms in adults with ADHD.

KEYWORDS

Autism Diagnostic Observation Schedule, Second Edition, attention deficit hyperactivity disorder, autism spectrum disorder, psychological disorders

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are common neurodevelopmental disorders affecting many children and adults worldwide.

The former is characterized by inattention, hyperactivity, and impulsivity, while the latter presents social communication deficits and restricted and repetitive behaviors.[1]

ADHD and ASD were previously considered separate, non-cooccurring disorders with different etiologies; nonetheless, recent studies have uncovered considerable similarities in clinical symptoms and behavioral problems between the two disorders. For example, in an epidemiological study by Simonof et al.,[2] 28.2% of children with ASD had ADHD symptoms. Similarly, 41% of children with ASD met the criteria for ADHD diagnosis in a twin study.[3] Moreover, in a general population in which ADHD and ASD traits were examined

together, a significant positive correlation was observed. The inattention and overall ADHD symptoms, measured using the Adult ADHD Self-Report Scale (ASRS) Symptom Checklist and Wender Utah Rating Scale, were positively correlated with the deficits in communication and social skills, as assessed using the Broad Autism Phenotype Questionnaire and the Autism Spectrum Quotient.[4] In a previous study, ~25% of adults with ADHD exhibited significant levels of ASD symptoms to the degree that they met the ASD cutoff score on the ADOS-2.[5] In addition, impulsivity symptoms correlated significantly with reciprocal social interaction deficits in ADHD-affected individuals.[5]

Not only symptomatology, but also familial, genetic, and imaging studies have revealed a few shared etiologies in both disorders. For instance, in their siblings' study, Mulligan et al. observed elevated ASD symptoms in both affected and non-affected siblings of a patient with ADHD, suggesting the shared familial risk factors between ADHD and ASD.[6] Several twin studies examined genetic correlations between ADHD and ASD symptoms and reported a significant influence of genetic factors on the covariance of ADHD and ASD symptoms.[3,7,8] Brieber et al. observed a gray matter increase in the left inferior parietal cortex and its reduction in the medial temporal lobe in adolescents with ADHD and those with ASD.[9] These significant overlaps and heterogeneities in the ADHD- and/or ASD-affected populations have led researchers to postulate that ADHD and ASD are different manifestations of the same overarching disorder.[8,10]

However, as they were once considered separate, significant differences remain between both disorders. In reviews of studies examining the neural similarities and differences in the brain structures and functioning using magnetic resonance imaging, more distinct neural correlates than shared neural features have been found between people with ADHD and ASD.[11,12] Moreover, Matsuura et al. used various cognitive and neurological assessments and found clear differences in the executive function of children with ADHD and those with ASD.[13] These findings suggest that each disorder is distinct despite their common co-occurrence.

Although studies on the ADHD–ASD relationship have risen recently, the complete picture remains unclear. Thus, further studies are required to determine the overlap and boundaries between the two neurodevelopmental disorders. Furthermore, although both disorders persist well into adulthood, most studies only investigated ADHD and ASD symptoms in children. Therefore, studies in adults are substantially lacking. Whether both disorders are different presentations of one comprehensive disorder and how manifestations and interactions of ADHD and ASD symptoms change over time need to be examined in detail. Therefore, to further reveal the similarities and differences between both neurodevelopmental disorders in adults, this study investigated adults with clinical ADHD and ASD and compared their ASD symptoms using the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2).[14] The ADOS-2 is a semi-structured assessment tool widely used to specifically evaluate ASD symptoms. It allows the detailed objective examination of the main symptoms of ASD: language and communication (LC), reciprocal social interaction (RSI), and restricted and repetitive behaviors (RRB).

METHODS

Participants

Participants were recruited from outpatient and inpatient centers at a university hospital between October 2018 and December 2020. Those fulfilling the DSM-5 criteria[1] for ADHD or ASD and with a full-scale IQ of over 85 using the Japanese version of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III)[15] were included. People with low IQ, including borderline IQ, are generally more likely to have psychiatric disorders and they might not fully understand the test, which might affect the test results. Hence in the present study, we focused on patients with relatively high IQs and no other psychiatric disorders. The exclusion criteria included age <17 years and the presence of mental disorders other than ADHD or ASD according to the DSM-5 criteria. Additionally, persons with a dual diagnosis of ASD and ADHD were excluded. The control group of neurotypical individuals comprised volunteer relatives or acquaintances of healthcare workers. Individuals diagnosed with mental disorders according to the DSM-5 criteria[1] and those who had first-order relatives with neurodevelopmental disorders were not included in the control group. Finally, the study included 69 adults with ADHD, 50 with ASD, and 31 normal controls. Of them, 63 individuals with ADHD and all controls had participated in a previous study.[5]

Procedure

The detailed diagnostic process is explained elsewhere.[5,16] All participants were individually administered a comprehensive clinical assessment, including (1) two sets of thorough interviews with participants and their caregivers on their developmental and medical history by psychiatrists and psychologists; (2) the Japanese version of Conners' Adult ADHD Diagnostic Interview for DSM-IV[17,18]; and (3) reviews of their maternity records and elementary school reports (at ages 6–12 years). The final diagnosis, if any, was determined by a consensus between the psychiatrists and psychologists based on the DSM-5 criteria. In this study, we did not use the ADOS or ADI-R (Autism Diagnostic Interview-Revised[19]) to diagnose ASD—the diagnosis was based on the clinicians' best estimates. However, the diagnosis was reliable as substantial time was spent collecting developmental and clinical information from multiple resources by experienced experts on neurodevelopmental disorders in adulthood. The participants of the control group underwent ~30-min interviews with a psychiatrist to confirm the absence of mental disorders and any neurodevelopmental disorder in their first-order relatives.

The above diagnostic process was followed by the administration of the following assessments to all the participants: (1) the ADOS-2 Module 4; (2) Conners' Adult ADHD Rating Scale-Self-Report: Long Version (CAARS-S:L-J)[20,21]; (3) the Autism Spectrum Quotient (AQ; 33 is considered the suitable cutoff)[22,23]; and (4) the WAIS-III.[15]

Autism Diagnostic Observation Schedule, Second Edition

The ADOS-2 Module 4 (standard and all optional activities) was administered by trained and certified psychiatrists blinded to the diagnoses. The total domain score was the sum of the LC, RSI, and RRB scores. The algorithm items for LC are A8 and A10; those for RSI are B1, B2, B5, B7, B9, B10, B11, and B12; and those for RRB are A2, A4, D1, D2, and D4. The revised algorithm was used in this study. Clinical and research cut-offs are set based on the ADOS-2 Module 4 research and the algorithm scores ≥8 and ≥10 are recommended as clinical and research cut-offs, respectively.[24] Participants with a total domain score ≥8 met the clinical cutoff for ASD diagnosis, and those with ≥10 met the research cutoff.[24] Details of the administration and scoring processes are explained in the previous study, and the administration has shown good inter-rater reliability.[5,16]

Statistical analysis

All statistical analyses were performed using SPSS Version 25.0 (IBM Corp.). The demographic (age, sex, and years of education), clinical (AQ, CAARS, and WAIS-III scores), and ADOS-2 score data were compared among the three groups: ASD, ADHD, and control groups. One-way analysis of variance (ANOVA) and χ^2 test were used for continuous and categorical variables, respectively. Bonferroni correction was employed for post hoc pairwise comparisons. For the ADOS-2 scores, in addition to calculating each domain score and the proportion of individuals meeting the cutoff, the proportion of non-zero scorers (those who scored 1, 2, 3, or 8 for B3) on each ADOS-2 item was calculated and compared among the three groups using ANOVA and post hoc Bonferroni correction. The significance level was set at 0.05. Pearson product–moment correlation coefficients were calculated among the scores of ADOS-2, AQ, CAARS, and WAIS-III to examine the relationship between each clinical measurement.

Ethics

This study was evaluated and approved by the appropriate ethics committee, and the protocols were carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all included participants after information was provided concerning the study.

TABLE 1 Demographic and clinical variables of the three groups.

	ASD (*n* = 50)		ADHD (*n* = 69)		Control (*n* = 31)		ANOVA	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	*F*-value	*p* value
Age	33.80 (8.39)	21–57	34.46 (10.84)	17–64	38.68 (6.75)	29–52	2.93	0.057
Sex (male) (*N* (%))	35 (70.0)		43 (62.3)		17 (54.8)		1.95[a]	0.382
Years of education	15.14 (2.19)	12–21	15.26 (1.80)	12–18	15.84 (1.34)	12–18	1.47	0.234
AQ: Total	33.14 (7.22)[a]	18–50	32.74 (8.14)[b]	11–48	13.39 (8.13)[a,b]	4–35	76.16	<0.001
CAARS: Inattention/Memory problems	64.38 (11.08)[c]	38–90	76.42 (12.31)[b,c]	37–90	51.55 (10.12)[b,c]	35–78	52.53	<0.001
CAARS: Hyperactivity/Restlessness	55.78 (12.46)[c]	39–89	64.12 (16.30)[b,c]	36–90	53.81 (12.97)[b,c]	34–90	7.55	0.001
CAARS: Impulsivity/Emotional lability	62.86 (13.18)[c]	39–90	69.36 (14.84)[b,c]	40–90	49.29 (10.90)[b,c]	34–70	23.42	<0.001
CAARS: Problems with self-concept	63.22 (11.76)[c]	37–85	68.26 (11.94)[b,c]	39–87	49.03 (10.74)[b,c]	34–73	29.28	<0.001
CAARS: DSM-IV inattentive	64.84 (12.00)[c]	42–90	77.43 (12.98)[b,c]	44–90	35.61(9.54)[b,c]	37–77	51.78	<0.001
CAARS: DSM-IV hyperactive-impulsive	60.94 (14.34)[c]	38–90	68.16 (17.43)[b,c]	38–90	51.42 (12.11)[b,c]	36–86	12.83	<0.001
CAARS: DSM-IV total ADHD symptoms	64.68 (13.29)[c]	40–90	75.19 (13.82)[b,c]	46–90	51.74 (10.58)[b,c]	36–79	35.60	<0.001
CAARS: ADHD index	66.78 (11.73)[c]	41–90	74.14 (11.61)[b,c]	43–90	48.52 (8.54)[b,c]	34–72	57.10	<0.001
WAIS-III: FIQ	105.68 (12.81)	85–132	106.25 (11.39)	85–136	107.35 (9.53)	91–129	0.72	0.817
WAIS-III: VIQ	109.32 (12.77)	86–136	107.78 (12.18)	81–137	106.06 (10.10)	85–131	3.18	0.490
WAIS-III: PIQ	99.76 (14.58)	71–131	103.39 (13.98)	72–134	107.58 (11.13)	87–128	0.20	0.045

Abbreviations: ADHD, attention deficit hyperactivity disorder; AQ, Autism Spectrum Quotient; ASD, autism spectrum disorder; CAARS, Conners' Adult ADHD Rating Scale; FIQ, full-scale IQ; PIQ, performance IQ; VIQ, verbal IQ; WAIS-III, Wechsler Adult Intelligence Scale Third Edition.

[a]The score of ASD is significantly lower than that of controls: $p < 0.01$.

[b]The score of ADHD is significantly lower than that of controls: $p < 0.01$.

[c]The score of ASD is significantly lower than both that of ADHD and controls: $p < 0.01$.

RESULTS

Demographic and clinical variables

Table 1 summarizes the demographic and clinical variables of the participants. In total, 150 persons participated; 69 participants had ADHD (mean age, 34.5 years [SD 10.8 years]; 43 men), 50 had ASD (mean age, 33.8 years [SD 8.4 years]; 35 men), and 31 were neurotypical controls (mean age, 38.7 years [SD 6.8 years]; 17 men). The study flow chart is shown in Figure 1. Seven subjects had dual diagnoses of ASD and ADHD, so they were excluded. In addition, the subjects who had other mental disorders, such as schizophrenia, were also excluded. All groups had relatively high average years of education and a similar sex proportion with a slight predominance of males. The average full-scale, verbal, and performance IQs were above 100 in the three groups except for performance IQ in the ASD group (full-scale IQ [FIQ], mean [M]: 105.7, SD: 12.8; verbal IQ [VIQ], M: 109.3, SD: 12.8; performance IQ [PIQ], M: 99.8, SD: 14.6), which was significantly lower than that of the controls (FIQ, M: 107.4, SD: 9.5; VIQ, M: 106.1, SD: 10.1; PIQ, M: 107.6, SD: 11.1) (FIQ, $F = 0.72$, $p = 0.82$; VIQ, $F = 3.18$, $p = 0.49$; PIQ, $F = 0.20$, $p = 0.05$). The AQ scores of the ADHD and ASD groups were significantly higher than those in the control group; however, they did not differ between the ADHD and ASD groups. All CAARS scores were significantly higher in the ADHD and ASD groups than in the control group, except for the hyperactivity/restlessness score, which did not differ between the ASD (Inattention/Memory problems, M: 64.38, SD: 11.08; Hyperactivity/Restlessness, M: 55.78, SD: 12.46; Impulsivity/Emotional lability, M: 62.86, SD: 13.18; Problems with self-concept, M: 63.22, SD: 11.76; DSM-IV Inattentive, M: 64.84, SD: 12.00; DSM-IV Hyperactive-impulsive, M: 60.94, SD: 14.34; DSM-IV Total ADHD symptoms, M: 64.68, SD: 13.29; ADHD Index, M: 66.78, SD: 11.73) and control groups (Inattention/Memory problems, M: 51.55, SD: 10.12; Hyperactivity/Restlessness, M: 53.81, SD: 12.97; Impulsivity/Emotional lability, M: 49.29, SD: 10.90; Problems with self-concept, M: 49.03, SD: 10.74; DSM-IV Inattentive, M: 35.61, SD: 9.54; DSM-IV Hyperactive-impulsive, M: 51.42, SD: 12.11; DSM-IV Total ADHD symptoms, M: 51.74, SD: 10.58; ADHD Index, M: 48.52, SD: 8.54) (Inattention/Memory problems, $F = 52.531$, $p = 0.000$; Hyperactivity/Restlessness, $F = 7.548$, $p = 0.001$; Impulsivity/Emotional lability, $F = 23.424$, $p = 0.000$; Problems with self-concept, $F = 29.275$, $p = 0.000$; DSM-IV Inattentive, $F = 51.776$, $p = 0.000$; DSM-IV Hyperactive-Impulsive, $F = 12.828$, $p = 0.000$; DSM-IV Total ADHD symptoms, $F = 35.604$, $p = 0.000$; ADHD index, $F = 57.102$, $p = 0.000$). Participants in the ADHD group scored significantly higher than those in the ASD group on all CAARS scales except for Problems with self-concept.

ADOS-2 total and domain scores

Table 2 presents the scores of the four domains (LC, RSI, SA, and RRB), total domain scores of the ADOS-2, and number of participants who met the ASD cutoff from the three groups. For all domain scores and the total domain score, adults with ASD scored significantly higher than those with ADHD and the controls. Participants with ADHD scored significantly higher than those in the control group on all domain scores and the total domain score, except for LC, in which no difference was observed between the ADHD and control groups. Furthermore, 74% of adults in the ASD group met the clinical ASD

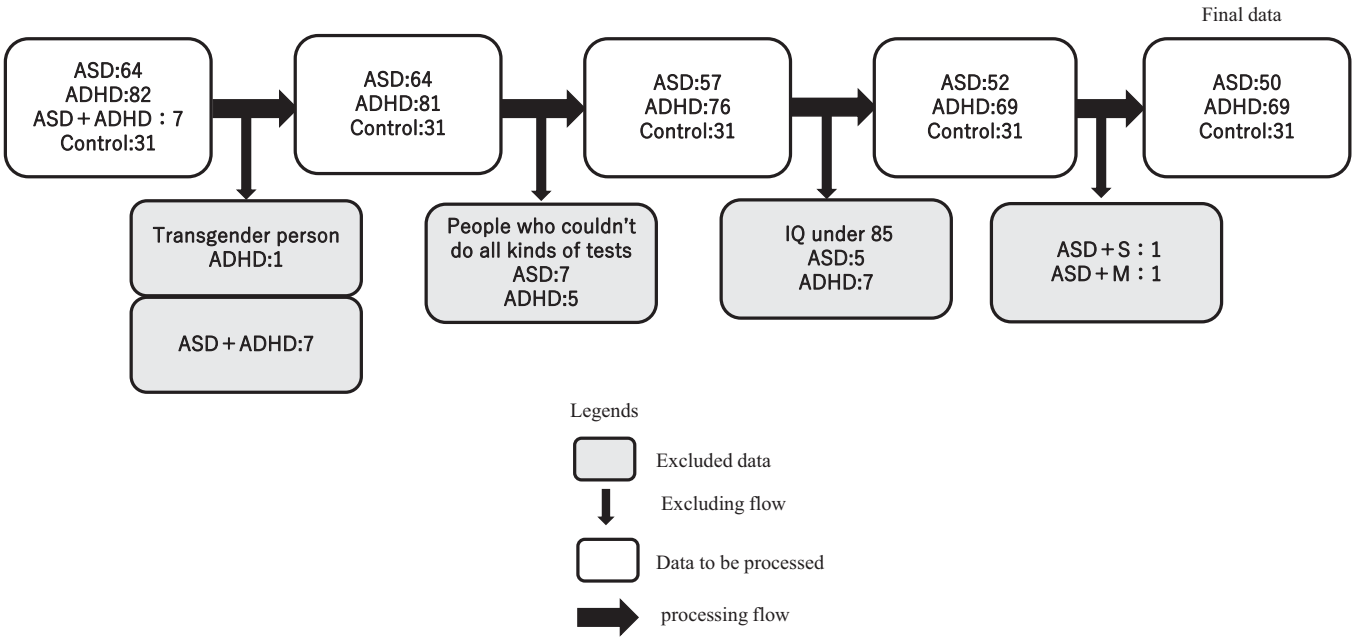

FIGURE 1 The number of the people who were excluded when we analyzed the data. ADHD, attention deficit hyperactivity disorder; ASD, autism spectrum disorder; M, manic depressive illness; S, schizophrenia.

TABLE 2 Mean domain scores and the percentage of participants who met the ASD cutoff from the three groups.

	ASD (n = 50)		ADHD (n = 69)		Control (n = 31)		ANOVA	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	F	p
ADOS-2: Rev LC	1.32 (0.89)[a,b]	0–4	0.88 (0.96)[a]	0–4	0.52 (0.63)[b]	0–2	8.39	<0.001
ADOS-2: Rev RSI	6.74 (2.35)[c]	0–12	3.55 (2.84)[c,d]	0–11	1.19 (1.08)[c,d]	0–4	54.34	<0.001
ADOS-2: Rev SA	8.06 (2.89)[c]	1–16	4.43 (3.62)[c,d]	0–14	1.71 (1.24)[c,d]	0–6	44.97	<0.001
ADOS-2: Rev RRB	1.24 (1.12)[c]	0–5	0.65 (0.97)[c,e]	0–5	0.10 (0.30)[c,e]	0–1	14.91	<0.001
ADOS-2: Rev total	9.30 (3.28)[c]	2–18	5.09 (4.11)[c,d]	0–15	1.81 (1.33)[c,d]	0–6	48.55	<0.001
	N	%	N	%	N	%	$\chi 2$	
Numbers of ASD (Clinical cut-off: 8)	37[c]	74.0	17,[c,e]	24.6	0,[c,e]	0.0	52.64	<0.001
Numbers of ASD (Research cut-off: 10)	26[c]	52.0	12[c]	17.4	0[c]	0.0	31.62	<0.001

Abbreviations: ADOS-2, Autism Diagnostic Observation Schedule, Second Edition; ASD, autism spectrum disorder; LC, language and communication; Rev, revised algorithm; RRB, restricted and repetitive behaviors; RSI, reciprocal social interaction; SA, social affect.

[a]The score of ASD is significantly lower than that of ADHD: $p < 0.05$.

[b]The score of ASD is significantly lower than that of control: $p < 0.01$.

[c]The score of ASD is significantly lower than both that of ADHD and control: $p < 0.01$.

[d]The score of ADHD is significantly lower than that of control: $p < 0.01$.

[e]The score of ADHD is significantly lower than that of control: $p < 0.05$.

cutoff, whereas 24.6% and 0% met the cutoff in the ADHD and control groups, respectively. Furthermore, 52.0%, 17.4%, and 0% of participants met the research ASD cutoff in the ASD, ADHD, and control groups, respectively. The among-group differences in the number of participants who met the ASD cutoffs were all significant—the ASD group had the highest percentage, whereas the controls had the lowest value.

ADOS-2 items

Table 3 compares the proportion of non-zero scorers on each ADOS-2 item among the three groups. The items that differed (endorsed significantly more in one group than the other) between the ASD and ADHD groups were A2 (speech abnormalities associated with autism), A9 (descriptive, conventional, instrumental, or informational gestures), A10 (emphatic or emotional gestures), B1 (unusual eye contact), B3 (language production and linked nonverbal communication), B9 (quality of social overtures), B11 (quality of social response), B12 (amount of reciprocal social communication), and D5 (compulsions or rituals). The items that differed between the ASD and control groups were A2, A8 (conversation), A9, A10, B1, B2 (facial expressions directed to examiner), B3, B4 (shared enjoyment in interaction), B5 (communication of own affect), B7 (insight into typical social situations and relationships), B8 (responsibility), B9, B11, B12, C1 (imagination/creativity), and D5. The items that differed between the ADHD and control groups were A2, A8, B2, B3, B4, B5, B7, B8, B9, B11, B12, and C1.

Figure 2 illustrates the details of ADOS-2 scoring on each item by each group: Figure 2a (A: language and communication domain), Figure 2b (B: reciprocal social interaction domain), and Figure 2c (C: imagination, D: stereotyped behaviors and restricted interests, E: other abnormal behaviors domains).

Correlations between ADOS-2, AQ, and CAARS

Pearson product–moment correlation coefficients among ADOS-2, AQ, and CAARS scores are shown for the ASD (Table 4a), ADHD (Table 4b), and control (Table 4c: from Hayashi et al.,[16]) groups. The ADOS-2 scores did not correlate with the AQ or CAARS scores in any of the three groups. The AQ scores mildly correlated with CAARS impulsivity and CAARS ADHD index scores in the ASD and ADHD groups. While the intrascale correlations were similar in the three groups, the ADOS-2 LC, RSI, and SA scores correlated with RRB scores only in the ADHD group.

DISCUSSION

This study compared ASD symptoms in adults with ADHD and those with ASD using the ADOS-2. The results revealed that individuals with ADHD present a certain degree of ASD symptoms that lay between those of ASD and neurotypical controls. Moreover, although eye-gesture–verbal coordination and compulsion differed between adults with ASD and those with ADHD, affect-related and insight into the social relationship presented similar scores in individuals with ASD and those with ADHD.

Consistent with previous studies, adults with ADHD exhibited significantly more ASD symptoms than neurotypical controls, as their domain scores were significantly higher than those of controls except for LC. The present study also revealed that ASD symptoms

TABLE 3 Non-zero scorers on each ADOS-2 item for the three groups.

	ASD (n = 50)	ADHD (n = 69)	Control (n = 31)	χ^2	p	Post-hoc pairwise[a]
A Language and communication	*N* (%)					
A1 Overall level of non-echoed spoken language	0 (0.0)	0 (0.0)	0 (0.0)	–	–	–
A2 Speech abnormalities associated with autism	38 (76.0)	25 (36.2)	1 (3.2)	43.59	<0.001	ASD > ADHD > Control
A3 Immediate echolalia	1 (2.0)	2 (2.9)	0 (0.0)	0.92	0.632	–
A4 Stereotyped/Idiosyncratic use of words or phrases	6 (12.0)	7 (10.1)	1 (3.2)	1.84	0.398	–
A5 Offers information	10 (20.0)	10 (14.5)	2 (6.5)	2.81	0.245	–
A6 Asks for information	45 (90.0)	57 (82.6)	22 (71.0)	4.84	0.089	–
A7 Reporting of events	12 (24.0)	19 (27.5)	8 (25.8)	0.19	0.910	–
A8 Conversation	16 (32.0)	19 (27.5)	2 (6.5)	7.29	0.026	ASD > Control, ADHD > Control
A9 Descriptive, conventional, instrumental, or informational gestures	24 (48.0)	18 (26.1)	6 (19.4)	9.27	0.010	ASD > Control, ASD > ADHD
A10 Emphatic or emotional gestures	37 (74.0)	33 (47.8)	13 (41.9)	10.87	0.004	ASD > Control, ASD > ADHD
B Reciprocal social interaction						
B1 Unusual eye contact	36 (72.0)	11 (15.9)	0 (0.0)	60.18	<0.001	ASD>Control, ASD > ADHD
B2 Facial expressions directed to examiner	33 (66.0)	32 (46.4)	2 (6.5)	27.61	<0.001	ASD > Control, ADHD > Control
B3 language production and linked nonverbal communication	45 (90.0)	23 (33.3)	0 (0.0)	69.97	<0.001	ASD > ADHD > Control
B4 Shared enjoyment in interaction	22 (44.0)	18 (26.1)	0 (0.0)	18.97	<0.001	ASD > Control, ADHD > Control
B5 Communication of own affect	27 (54.0)	28 (40.6)	8 (25.8)	6.35	0.042	ASD > Control, ADHD > Control
B6 Comments on others' emotions/Empathy	17 (34.0)	26 (37.7)	8 (25.8)	1.34	0.511	–
B7 Insight into typical social situations and relationships	40 (80.0)	54 (78.3)	15 (48.4)	11.64	0.003	ASD > Control, ADHD > Control
B8 Responsibility	19 (38.0)	22 (31.9)	3 (9.7)	7.81	0.020	ASD > Control, ADHD > Control
B9 Quality of social overtures	44 (88.0)	20 (29.0)	0 (0.0)	70.36	<0.001	ASD > ADHD > Control
B10 Amount of social overtures/Maintenance of attention	28 (56.0)	30 (43.5)	9 (29.0)	5.70	0.058	–
B11 Quality of social response	41 (82.0)	19 (27.5)	0 (0.0)	61.88	<0.001	ASD > ADHD > Control
B12 Amount of reciprocal social communication	33 (66.0)	24 (34.8)	1 (3.2)	32.61	<0.001	ASD > ADHD > Control
B13 Overall quality of rapport	12 (24.0)	7 (10.1)	2 (6.5)	6.47	0.039	–
C Imagination						
C1 Imagination/Creativity	34 (68.0)	32 (46.4)	10 (32.3)	10.72	0.005	ASD > Control, ADHD > Control
D Stereotyped behaviors and restricted interest						
D1 Unusual sensory interest in play material/Person	1 (2.0)	1 (1.4)	0 (0.0)	0.60	0.743	–
D2 Hand and finger and other complex mannerisms	3 (6.0)	3 (4.3)	0 (0.0)	1.83	0.400	–
D3 Self-injurious behavior	0 (0.0)	0 (0.0)	0 (0.0)	–	–	–
D4 Excessive interest in or reference to unusual or highly specific topics or objects or repetitive behaviors	7 (14.0)	4 (5.8)	1 (3.2)	3.86	0.145	–
D5 Compulsions or rituals	14 (28.0)	5 (7.2)	1 (3.2)	14.26	0.001	ASD>Control, ASD > ADHD
E Other abnormal behaviors						

TABLE 3 (Continued)

	ASD ($n = 50$)	ADHD ($n = 69$)	Control ($n = 31$)	χ^2	p	Post-hoc pairwise[a]
E1 Overactivity/Agitation	5 (10.0)	12 (17.4)	1 (3.2)	4.35	0.114	–
E2 Tantrums, aggression, negative or disruptive behavior	0 (0.0)	1 (1.4)	0 (0.0)	1.18	0.554	–
E3 Anxiety	2 (4.0)	9 (13.0)	1 (3.2)	4.43	0.109	–

Abbreviations: ADHD, attention-deficit hyperactivity disorder; ADOS-2, Autism Diagnostic Observation Schedule, Second Edition; ASD: autism spectrum disorder.

[a]With Bonferroni correction, inequality signs indicating differences at $p < 0.05$.

presented by ADHD-affected individuals were not at the same level as those exhibited by the ASD-affected counterparts, and all the domain scores of the ADHD group were lower than those of the ASD group. Although the results showing that adults with ADHD present social communication difficulties are not entirely novel, our results add to a previous study showing that adults with ADHD also exhibit a certain level of restricted and repetitive behaviors and interests.[25] These results underline the importance of assessing social communication difficulties and restricted and repetitive behaviors and interests in individuals with ADHD in clinical practice.

No participants in the control group met the ASD cutoff using the ADOS-2; however, approximately one-quarter of adults with ADHD met the cutoff despite not being clinically diagnosed with ASD. This highlights the importance of the combined use of ADOS-2, ADI-R, a detailed neurodevelopmental history, and collateral information in diagnosing ASD in adults with ADHD but also proposes the need for carefully examining ASD symptoms in ADHD-affected adults even when they do not meet the diagnostic threshold of ASD.[5] In contrast, approximately one in four adults with ASD did not meet the ASD cutoff using the ADOS-2. ADOS-2 is a useful tool in assessing ASD symptoms; nevertheless, some studies have reported the limited specificity and sensitivity of Module 4 for adults with moderate-to-high verbal IQs.[26] The average-to-high-level verbal IQ observed in our sample or factors such as camouflaging effects[27,28] may have affected the cutoff threshold. Thus, further studies are needed to investigate the suitable cutoff for different ASD populations.

We did not find any correlation between the scores of CAARS and ADOS-2. This indicates that the presence of ASD symptoms might not be associated with the severity of ADHD symptoms. It is particularly noteworthy that the scores of AQ and ADOS-2 did not show a correlation. It might be the difference between self-reported and observed evaluations, which highlights the importance of examining both self-reported and observed tests.

In close observation of item-level analysis, several important insights were revealed regarding ADHD–ASD overlap and differences. Nine items were significantly more endorsed in adults with ASD than their ADHD counterparts; however, seven were endorsed at the same frequency in both groups. Specifically, items evaluating eye contact–gesture–verbal output coordination (i.e., the "quality" of communication) differed between the ADHD and ASD groups. These items include descriptive (A9) and emphatic (A10) gestures, eye contact (B1), verbal–nonverbal coordination (B3), quality of social overture (B9), and response (B11). In addition, the level of reciprocity in social communication (B12) and compulsions or rituals (D5) also distinguished ASD from ADHD.

Contrarily, affect-related items, such as facial expression toward the examiner (B2), sharing enjoyment (B4), communicating own affect (B5), insight into social relationships (B7), responsibility (B8), conversation (A7), and imagination (C), did not differ between the ADHD and ASD group. These results are generally consistent with the ADOS-2 scores from children with ADHD and ASD in a study by Grzadzinski et al.[29] In their study, children with ASD scored more on the quality of social overtures and responses, abnormal eye contact, and the level of reciprocal social interaction than their ADHD-affected counterparts. In contrast, the two groups did not differ in the score on sharing enjoyment, which is consistent with the results of adult patients in this study. In contrast to our findings, more items distinguished children with ASD and ADHD, including conversation, facial expression directed towards the examiner, and D items other than compulsions or rituals. Moreover, children in the two groups did not differ in descriptive gestures and compulsions or rituals, which differs from our results on adults. Direct comparison is inappropriate because the modules used and some demographical and clinical characteristics differ. However, the quality of social communication, particularly how a person coordinates eye contact with other verbal and non-verbal communication, is a reasonable key phenotypic boundary between ASD and ADHD. Although most RRB (D) items distinguish children with the two disorders, only compulsions or rituals did in adults. Overt stereotypic behaviors might be reduced or become disguised in adulthood in those with ASD, and the gap between them and ADHD-affected individuals might narrow. However, Hus and Lord[24] reported that observing enough RRBs in Module 4 is challenging. This is also indicated by our results showing a low frequency of item D endorsement in all three groups, which may have contributed to the minimal difference in those items between the ADHD and ASD groups. Additional assessments to examine the differences in ASD and ADHD in terms of RRBs are necessary.

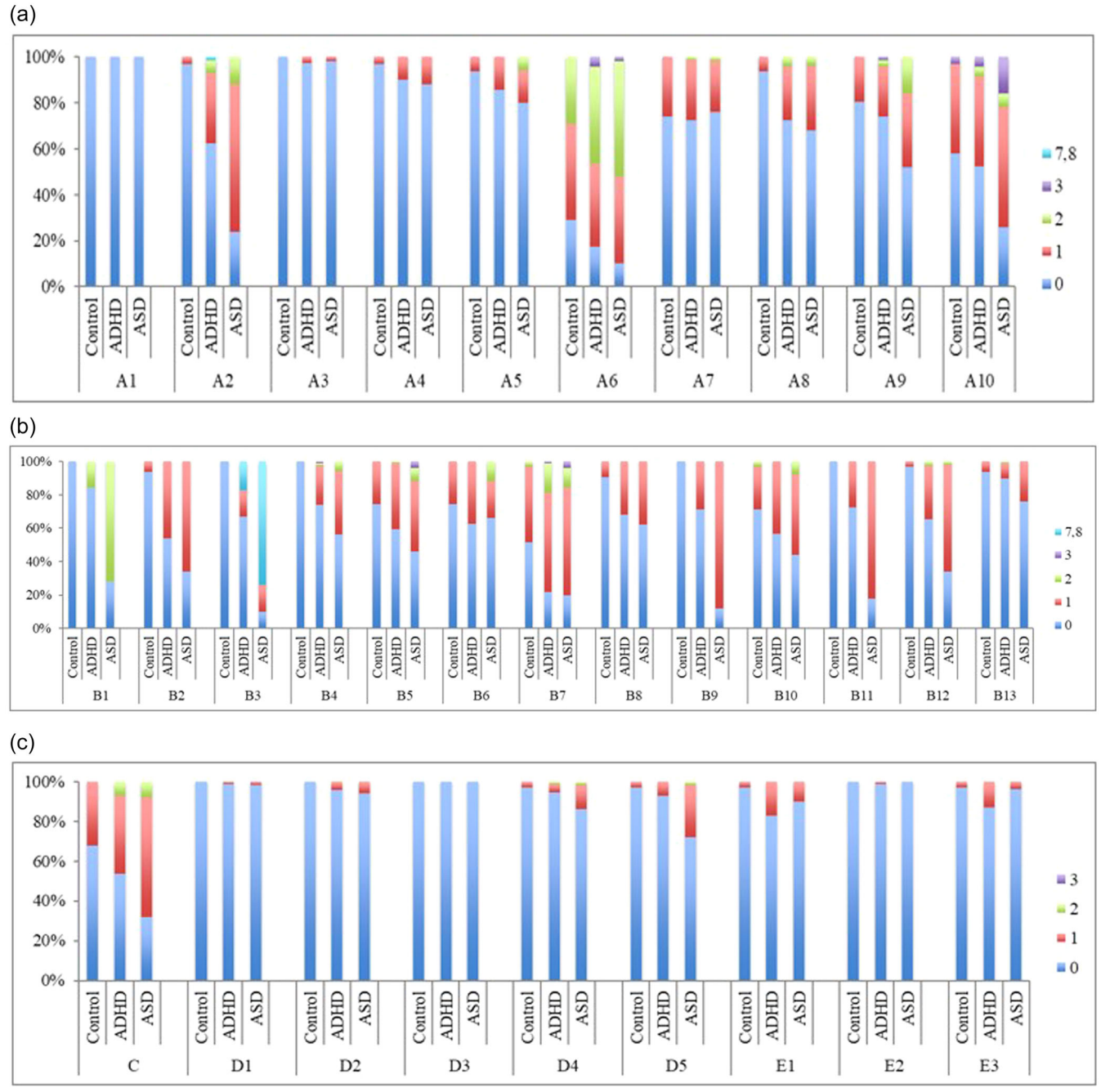

FIGURE 2 Percentage of each score on all Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) items for the autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), and control groups for (a) language and communication (A); (b) reciprocal social interaction (B); and (c) imagination (C), stereotyped behaviors and restricted interests (D), and other abnormal behaviors (E) domains.

Regarding ADHD–ASD overlap, our results were not fully consistent with the juvenile study[29]; nonetheless, affect-related items were found to be similar in the two disorders. Although the literature is limited, studies have revealed affect-related impairments in individuals with ADHD. For example, Parke et al.[30] reported that children with ADHD performed worse on affect-recognition measurements than controls. Similarly, Staff et al.[31] observed that children who met the ADHD diagnosis and those at the subthreshold level exhibited impairments in facial emotion recognition.

In addition, as discussed in previous studies,[5,16] insight into relationships and roles in adults with ADHD may be as compromised as those with ASD owing to repeated social failure resulting from inattention or impulsivity. Moreover, besides the ADHD–ASD overlapping items, a few were scored significantly higher in adults with ADHD than in controls. These include speech abnormalities

TABLE 4a Correlations between AQ, CAARS, WAIS-III, and ADOS-2 in the ASD group ($n = 50$).

	AQ: Total	CAARS: Inatt	CAARS: Hype	CAARS: Imp	CAARS: ADHD Index	WAIS-III: VIQ	WAIS-III: PIQ	WAIS-III: FIQ	ADOS-2:Rev LC	ADOS-2: Rev RSI	ADOS-2: Rev SA	ADOS-2:Rev RRB	ADOS-2: Rev Total
AQ: Total		0.25	−0.05	0.42*	0.46*	0.10	0.23	0.17	−0.11	−0.03	−0.06	−0.09	−0.08
CAARS: Inatt			0.43*	0.49*	0.57*	0.25	0.47*	0.41*	−0.22	0.06	−0.02	−0.21	−0.09
CAARS: Hype				0.45*	0.45*	0.09	0.31	0.22	−0.08	0.23	0.16	0.03	0.15
CAARS: Imp					0.81*	0.08	0.28	0.19	−0.16	0.11	0.04	0.10	0.07
CAARS: ADHD Index						0.12	0.32	0.24	−0.21	0.04	−0.04	−0.01	−0.03
WAIS-III: VIQ							0.49*	0.88*	0.05	0.13	0.12	0.10	0.13
WAIS-III: PIQ								0.84*	0.14	0.15	0.17	0.02	0.15
WAIS-III: FIQ									0.10	0.16	0.16	0.07	0.16
ADOS−2:Rev LC										0.49*	0.71*	0.23	0.70*
ADOS−2:Rev RSI											0.96*	0.13	0.89*
ADOS−2:Rev SA												0.18	0.94*
ADOS-2:Rev RRB													0.50*

Abbreviations: ADHD, attention deficit hyperactivity disorder; ADOS-2, Autism Diagnostic Observation Schedule, Second Edition; AQ, Autism Spectrum Quotient; ASD, autism spectrum disorder; CAARS, Conners' Adult ADHD Rating Scale; FIQ, full-scale IQ; Hype, Hyperactivity/Restlessness; Inatt, Inattention/Memory problems; Imp, Impulsivity/Emotional lability; LC, language and communication; PIQ, performance IQ; Rev, revised algorithm; RRB, restricted and repetitive behaviors; RSI, reciprocal social interaction; SA, social affect; VIQ, verbal IQ; WAIS-III, Wechsler Adult Intelligence Scale, Third Edition.

*Correlation is significant at the 0.01 level (two-tailed).

TABLE 4b Correlations between AQ, CAARS, WAIS-III, and ADOS-2 in the ADHD group ($n = 69$).

	AQ: Total	CAARS: Inatt	CAARS: Hype	CAARS: Imp	CAARS: ADHD Index	WAIS-III: VIQ	WAIS-III: PIQ	WAIS-III: FIQ	ADOS-2:Rev LC	ADOS-2: Rev RSI	ADOS-2: Rev SA	ADOS-2:Rev RRB	ADOS-2: Rev Total
AQ: Total		0.27	0.26	0.49*	0.51*	0.03	0.10	0.10	0.13	0.21	0.20	0.09	0.20
CAARS: Inatt			0.38*	0.55*	0.66*	−0.02	−0.03	−0.02	0.06	0.07	0.07	0.12	0.09
CAARS: Hype				0.66*	0.75*	−0.05	−0.21	−0.11	0.14	0.15	0.15	0.00	0.14
CAARS: Imp					0.85*	−0.14	0.06	0.00	0.10	0.11	0.12	−0.01	0.10
CAARS: ADHD Index						−0.09	−0.06	−0.06	0.15	0.22	0.22	0.07	0.21
WAIS-III: VIQ							0.36*	0.81*	0.04	0.08	0.07	−0.12	0.03
WAIS-III: PIQ								0.76*	0.18	0.17	0.18	0.08	0.18
WAIS-III: FIQ									0.19	0.19	0.20	−0.01	0.18
ADOS-2:Rev LC										0.75*	0.86*	0.37*	0.84*
ADOS-2:Rev RSI											0.99*	0.39*	0.96*
ADOS-2:Rev SA												0.40*	0.98*
ADOS-2:Rev RRB													0.59*

Abbreviations: ADHD, attention deficit hyperactivity disorder; ADOS-2, Autism Diagnostic Observation Schedule, Second Edition; AQ, Autism spectrum quotient; CAARS, Conners' Adult ADHD rating scale; FIQ, full-scale IQ; Hype, Hyperactivity/Restlessness; Imp, Impulsivity/Emotional lability; Inatt, Inattention/Memory problems; LC, language and communication; PIQ, performance IQ; Rev, revised algorithm; RRB, restricted and repetitive behaviors; RSI, reciprocal social interaction; SA, social affect; VIQ, verbal IQ; WAIS-III, Wechsler Adult Intelligence Scale, Third Edition.

*Correlation is significant at the 0.01 level (two-tailed).

TABLE 4c Correlations between AQ, CAARS, WAIS-III, and ADOS-2 in the control group ($n = 31$).

	AQ: Total	CAARS: Inatt	CAARS: Hype	CAARS: Imp	CAARS: ADHD Index	WAIS-III: VIQ	WAIS-III: PIQ	WAIS-III: FIQ	ADOS-2:Rev LC	ADOS-2: Rev RSI	ADOS-2: Rev SA	ADOS-2:Rev RRB	ADOS-2: Rev Total
AQ: Total		0.15	−0.16	0.14	0.23	−0.12	−0.24	−0.21	−0.05	0.32	0.25	0.38	0.32
CAARS: Inatt			0.55*	0.63*	0.68*	0.28	0.13	0.26	0.12	0.35	0.36	0.20	0.39
CAARS: Hype				0.51*	0.67*	0.07	−0.20	−0.06	−0.24	−0.16	−0.26	−0.08	−0.26
CAARS: Imp					0.76*	0.49*	−0.09	0.28	−0.06	0.09	0.05	0.10	0.07
CAARS: ADHD Index						0.25	−0.24	0.04	−0.03	0.08	0.05	0.01	0.05
WAIS-III: VIQ							0.36	0.86*	0.23	0.16	0.25	0.10	0.26
WAIS-III: PIQ								0.79*	0.13	0.27	0.30	0.13	0.31
WAIS-III: FIQ									0.22	0.26	0.34	0.14	0.35
ADOS-2: Rev LC										−0.01	0.50*	−0.28	0.41
ADOS-2: Rev RSI											0.86*	0.35	0.89*
ADOS-2: Rev SA												0.17	0.98*
ADOS-2: Rev RRB													0.38

Note: This is the same table as the previous study.[5]

Abbreviations: ADHD, attention deficit hyperactivity disorder; ADOS-2, Autism Diagnostic Observation Schedule, Second Edition; AQ, Autism Spectrum Quotient; CAARS, Conners' Adult ADHD rating scale; FIQ, full-scale IQ; Inatt, Inattention/Memory problems; Hype, Hyperactivity/Restlessness; Imp, Impulsivity/Emotional lability; LC, language and communication; PIQ, performance IQ; Rev, revised algorithm; RRB, restricted and repetitive behaviors; RSI, reciprocal social interaction; SA, social affect; VIQ, verbal IQ; WAIS-III, Wechsler Adult Intelligence Scale, Third Edition.

*Correlation is significant at the 0.01 level (two-tailed).

associated with autism, conversation, social overtures and response quality, and the level of reciprocity in social communications. Only four items did not differentiate the ADHD group from the control group. This finding supports the previous work showing that adults with ADHD present marked ASD symptoms,[5,16] and the key ASD–ADHD differentiating feature, which is the "quality" of social communication, is degree rather than quality. This also supports the notion that both disorders are manifestations of one overarching disorder.[8,10] Longitudinal studies are required to uncover how ASD–ADHD symptoms manifest and interact over the life period.

Some items, including most D and E items and some A items, were scored similarly in the three groups. One reason, particularly for D and E items, is the low endorsement frequencies. However, as discussed in previous studies,[5] some A items, such as offering information (A5), asking for information (A6), and level of social overtures (A10), may be related to cultural differences between the Eastern and Western countries.[32,33] Asking or offering too much information, including personal episodes and emotions, is uncommon, especially when meeting an individual for the first time or when the other person is in authority (such as the examiner). Accordingly, cultural differences should be examined in future studies.

This study had several limitations that should be considered. First is the accuracy of the clinical ASD and ADHD diagnoses. The effect should not be significant because a thorough developmental history with collateral information was considered for the diagnosis. Nevertheless, the possibility that individuals with ASD were included in the ADHD group and vice versa remained. Second, the inclusion of medicated adults may have altered the ADOS-2 performance. Finally, although individuals with other psychiatric disorders were excluded, subclinical levels of depression and anxiety may have affected the ADOS-2 scores. Future studies need to target medication-naive individuals, with other scales assessing the ADHD and ASD symptoms and the level of depression and anxiety.

CONCLUSION

ADOS-2 performance revealed a significant symptom overlap between adults with ADHD and those with ASD. The "quality" of social communication distinguished the two disorders; however, the difference may be of degree, as adults with ADHD scored significantly more on most ADOS-2 items than controls, and adults with ADHD frequently endorsed as many items as their ASD counterparts. This study highlights the importance of assessing full ASD symptoms in adults with ADHD. Further studies from various angles, including neuroimaging, genetics, and symptomatology, are required to clarify the ADHD–ASD relationship.

AUTHOR CONTRIBUTIONS

Yoichi Hanaw analyzed the data and wrote the bulk of the manuscript. Wakaho Hayashi and Dan Nakamura helped design and conceptualize the study, assessed participants, and wrote and edited sections of the manuscript. Hirohisa Suzuki, Misato Yamauchi, and Shizuka Seki helped with statistical analysis and reviewed drafts of the paper. Yuriko Iwami and Keisuke Aoyagi were involved with conceptualization of the study, participant recruitment, and assessment. Akira Iwanami oversaw all aspects of the study from study conceptualization, data collection, data analysis, and manuscript writing.

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CONFLICT OF INTEREST STATEMENT

Akira Iwanami is an Editorial Board member of *Psychiatry and Clinical Neurosciences Reports* and a co-author of this article. To minimize bias, they were excluded from all editorial decision-making related to the acceptance of this article for publication.

DATA AVAILABILITY STATEMENT

Data used in preparation of this manuscript are available on request from the corresponding author, Yoichi Hanawa. The data are not publicly available due to restrictions (e.g., their containing information that could compromise the privacy of research participants).

ETHICS APPROVAL STATEMENT

This study was evaluated and approved by the Medical Ethics Committee of Showa University School of Medicine, and the protocols were carried out in accordance with the Declaration of Helsinki.

PATIENT CONSENT STATEMENT

Written informed consent was obtained from all participants included in the study after information was provided about the study.

CLINICAL TRIAL REGISTRATION

N/A.

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