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Impact of Comorbid Oppositional Defiant Disorder on the Clinical and Neuropsychological Characteristics of Korean Children With Attention-Deficit/Hyperactivity Disorder

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Objective The aim of the present study was to investigate the influence of comorbid oppositional defiant disorder (ODD) on clinical features and neuropsychological profiles of children with attention-deficit/hyperactivity disorder (ADHD).

Methods We divided the participants into three groups: the ADHD with ODD (ADHD/ODD) (n=36), ADHD without ODD (ADHD/noODD) (n=307), and control groups (n=128). Parents of the participants completed the ADHD Rating Scale, Social Responsiveness Scale (SRS), Korean Personality Rating Scale for Children (K-PRC), and 10-item mania scale from the Parent General Behavior Inventory (P-GBI-10M). Neuropsychological profiles were assessed using the Advanced Test of Attention (ATA), Children's Color Trails Test, and Stroop Color and Word Test.

Results The ADHD/ODD group had more ADHD symptoms and functional impairments in relationships with teachers and peers, and self-esteem than the ADHD/noODD group. The ADHD/ODD group scored higher in Social Communication ($p<0.001$) and Autistic Mannerisms ($p<0.001$) subscales of SRS, P-GBI-10M ($p<0.001$), and Delinquency ($p<0.001$) and Psychosis ($p<0.001$) subscales of K-PRC than the ADHD/noODD group. Commission Errors ($p<0.001$) and Response-Time Variability ($p<0.001$) in Visual ATA and Commission Errors ($p<0.001$) in Auditory ATA were significantly higher in the ADHD/ODD group than in the ADHD/noODD group.

Conclusion The present study suggests that patients with ADHD with ODD experience more ADHD symptoms and neuropsychological deficits than those with ADHD without ODD. These results also imply that comorbid ODD is associated with greater social impairment and emotional dysregulation.

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Keywords ADHD; Oppositional defiant disorder; Functional impairment; Emotional regulation; Neuropsychological profile.

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning.[1] It is a common neurobehavioral disorder in children and adolescents, affecting approximately 3%−7% of school-age children, with a greater prevalence among boys.[2] Children with ADHD are likely to experience functional impairments in diverse settings, such as at home, school, or work, with friends or relatives, and in other activities.[1] Patients with ADHD tend to have a high comorbidity rate with other psychiatric disorders.[3-6] In a nationwide study in Korea, approximately 60% of the children and adolescents with ADHD had at least one psychiatric comorbidity.[7] Moreover, comorbid disorders with ADHD can contribute to more severe functional impairments in academic, social, and emotional dimensions.[8]

Oppositional defiant disorder (ODD) is a frequent condition associated with ADHD, with a comorbidity incidence rate of 50%−60%.[5-8] ODD is a disruptive behavior disorder characterized by angry or irritable mood, argumentative or defiant behavior, and vindictiveness,[1] and children and adolescents with ODD may experience trouble controlling their temper and often resist conforming to others.[9] Children and adolescents with ADHD and ODD more frequently receive the prescribed pharmacological and psychological treatment than those with ADHD alone,[5] suggesting the clinical signifi-

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cance of comorbid ODD in children with ADHD. Furthermore, Noordermeer et al.[10] have suggested that hot executive functioning-related structures (i.e., amygdala, insula, and anterior cingulate) are more closely related to ODD and conduct disorder and the cool executive functioning-related structures (i.e., dorsolateral prefrontal cortex and cerebellum) are more closely associated with ADHD, resulting in profound impairments observed in the comorbidity of these disease.

Previous studies[11-13] revealed that comorbid ODD is associated with greater severity of inattentive and hyperactive-impulsive symptoms and more behavior problems in children with ADHD than in those without comorbid ODD, suggesting its negative effect on ADHD symptoms. However, the frequency of symptom presentations in diverse settings or specific domains of functional impairments was left unexplored. Moreover, literature examining social impairments and emotional regulation in children with ADHD with and without ODD was scarce. A study demonstrated that comorbid ODD in children with ADHD was associated with high prevalence of symptoms of major depressive disorder,[11] emphasizing the need for further exploration of the impact of ODD on the emotional well-being of children with ADHD. Previous studies also implied that comorbid ODD in children and adolescents with ADHD could affect social impairments.[14-16] However, the social function of these children and adolescents has not yet been evaluated. Therefore, the aim of the present study was to evaluate the impact of comorbid ODD in children and adolescents with ADHD in terms of clinical and neuropsychological profiles by investigating ADHD with ODD (ADHD/ODD), ADHD without ODD (ADHD/noODD), and control groups, focusing on the social and emotional domains.

METHODS

Participants

We recruited 471 children, aged 5−14 years, at the outpatient clinic of the Department of Pediatric Psychiatry of the Asan Medical Center, Seoul, Korea, between April 2012 and May 2020. We diagnosed 36 patients with ADHD and ODD (ADHD/ODD group), 307 patients with ADHD without ODD (ADHD/noODD group), and 128 patients with neither ADHD nor ODD (control group). The control group was recruited through an internet bulletin board at the Asan Medical Center.

We excluded participants who met one or more of the following criteria: 1) intelligence quotient <70; 2) past and/or current history of schizophrenia, organic mental disorder, or pervasive developmental disorder; 3) a diagnosis of neurologic disorders, including seizures; 4) administration of methylphenidate or atomoxetine within the last 6 months or for >3 months even if taken before 6 months; and 5) major depression disorder or tic disorder requiring medication. The group of patients was selected based on consecutive enrollment, with written informed consent obtained from the parents and written assent from the participants. The Institutional Review Board of the Asan Medical Center approved the study protocol (IRB no. 2014-0157).

Diagnosis

ADHD, ODD, and comorbid psychiatric disorders were diagnosed by three board-certified child and adolescent psychiatrists, according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR) and confirmed using Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version (K-SADS-PL). Three raters independently rated 20% of the K-SADS-PL tape, and the kappa coefficients ranged from 0.76 to 0.90. Discrepancies were resolved through consensus.

ADHD subtypes were identified according to the DSM-IV-TR criteria. ADHD not otherwise specified (NOS) was operationally defined as the presence of three to five inattentive and/or hyperactive/impulsive symptoms. Participants fulfilling the DSM-IV-TR ADHD impairment criteria were diagnosed with ADHD NOS.

Symptoms of ADHD were evaluated across numerous settings, including at home, at school, in peer relationships, and in other activities. Functional impairment was rated across six domains, including academic functioning, relationship with teachers, peer relationship, relationship with parents, participation in leisure activities, and self-esteem. The presence of symptoms and functional impairment were assessed as a binary variable (yes/no).

Assessments

ADHD Rating Scale

The severity of ADHD symptoms was assessed based on the Korean version of ADHD Rating Scale (ARS), which was administered by the parents of the participants. The Korean version of ARS is an 18-item scale comprising two subscales: inattention and hyperactivity-impulsivity, with 9 items each. It is a 4-point rating scale as follows: 0=none; 1=mild; 2=moderate; and 3=severe. The reliability and validity of the Korean version of ARS were previously verified.[17]

Social Responsiveness Scale

Impaired social abilities and atypical social interactions were evaluated using Social Responsiveness Scale (SRS), which was completed by the parents of the participants. SRS is a 65-item scale with five symptom domains: social awareness, so-

cial cognition, social communication, social motivation, and autistic mannerisms.[18] The cross-cultural validity of the scale for detecting autistic traits was investigated.[19]

Parent General Behavior Inventory

Depressive and hypomanic/biphasic symptoms were assessed using Parent General Behavior Inventory (P-GBI). The 10-item Mania Scale from P-GBI (P-GBI-10M), a brief version of P-GBI, was used. The 10 items include symptoms, such as elated mood, high energy, irritability, and rapid changes in mood and energy.[20] The diagnostic validity and reliability of the Korean version of P-GBI-10M were previously validated.[21]

Korean Personality Rating Scale for Children

Behavioral characteristics related to psychiatric disorders were evaluated using Korean Personality Rating Scale for Children (K-PRC). K-PRC based on the personality inventory for children, child behavior checklist, and DSM-IV.[22] It is a 4-point rating scale comprising 177 items across 10 subscales: verbal development, physical development, anxiety, depression, somatization, delinquency, hyperactivity, family relationship, social relationship, and psychosis. The test was previously standardized for Korean children and adolescents, and its reliability and validity were previously established.[22]

Advanced Test of Attention

A neuropsychological assessment of attention was performed using Advanced Test of Attention (ATA). ATA is a continuous performance test consisting of visual and auditory attention tests. Four indices are measured, each indicating different attention profiles: 1) omission errors designates sustained attention; 2) commission errors reflects impulsivity and inhibitory control; 3) response time evaluates attention distraction and task performance speed; and 4) response time variability, or standardized deviations of response time, shows the consistency of attention.[23] The reliability and validity of the test were previously verified in a standardized study.[24]

Stroop Color and Word Test

The ability to inhibit cognitive interference was assessed using Stroop Color and Word Test (SCWT). Test cards contain colored words, and three experiments are run: 1) reading the words aloud (word score); 2) speaking the color of the word (color score); and 3) speaking the color of the word, regardless of its meaning, when the word itself spells another color (color-word score). The Korean version of SCWT−Children's Version was standardized and certified as a reliable tool to estimate response suppression in the frontal lobe.[25]

Children's Color Trails Test

Children's Color Trails Test (CCTT) is a modified trail making test adjusted to the cognitive processing capacity of children. CCTT consists of two parts: CCTT1 and CCTT2. In CCTT1, the respondent is asked to connect randomly arranged numbers following the number sequence. In CCTT2, the respondent connects both numbers and letters, alternating between them. CCTT1 assesses psychomotor speed and sequential processing capability, while CCTT2 evaluates cognitive flexibility and sustained attention. CCTT has been proven reliable and valid and can be used to evaluate frontal function.[26]

Statistical analysis

Categorical variables were compared using the chi-square or Fisher's exact tests. Continuous variables were compared using one-way analysis of variance, and when significant differences were found among the three groups, the post hoc Games−Howell test was performed. Analysis of covariance (ANCOVA) was used to adjust for age, sex, comorbid tic disorder, and Full-Scale Intelligence Quotient (FSIQ). For ARS, SRS, and P-GBI, ANCOVA was used to adjust for age, sex, and comorbid tic disorder. For K-PRC, FSIQ, and ATA, which provide age and sex standardized scores, age and sex were not adjusted again. ANCOVA was used to adjust for comorbid tic disorder in K-PRC and FSIQ. For ATA, ANCOVA was used to adjust for FSIQ. For SCWT, ANCOVA was used to adjust for age, sex, and FSIQ. Statistical significance was defined as a $p<0.05$. Statistical analyses were performed using IBM Statistical Package for the Social Sciences for Windows, version 26 (IBM Corp., Armonk, NY, USA).

RESULTS

Demographic and clinical characteristics

We enrolled 36 participants in the ADHD/ODD group (age=7.8±1.9 years, range=5−14 years, 33 boys and 3 girls), 307 in the ADHD/noODD group (age=7.7±1.8 years, range=5−14 years, 257 boys and 50 girls), and 128 in the control group (age=8.2±2.5 years, range=5−14 years, 65 boys and 63 girls). Boys were predominant in both the ADHD/ODD and ADHD/noODD groups ($\chi^2=58.35$, $p<0.001$), and significant differences were observed between the ADHD/ODD and control groups ($\chi^2=19.53$, $p<0.001$), as well as between the ADHD/noODD and control groups ($\chi^2=7.54$, $p=0.006$). The rate of comorbid tic disorder differed significantly between the ADHD/noODD and control groups ($\chi^2=7.52$, $p=0.023$), and a significant difference was observed between the ADHD/ODD and control groups ($p<0.001$) (Table 1).

Table 1. Demographic and clinical characteristics of the ADHD/ODD, ADHD/noODD, and control groups

	ADHD/ODD (OA, N=36)	ADHD/noODD (A, N=307)	Control (C, N=128)	F, t, or χ^2	p	Post-hoc
Age (yr)	7.8±1.9	7.7±1.8	8.2±2.5	2.52	0.086*	
Age of onset, N=340 (yr)	5.7±2.0	5.8±1.5	-	1.91	0.168*	
Sex				58.35	<0.001†	
Boys	33 (91.7)	257 (83.7)	65 (50.8)			OA>C, A>C
Girls	3 (8.3)	50 (16.3)	63 (49.2)			
ADHD subtype				7.08	0.052‡	
Inattentive	11 (30.6)	139 (45.3)	-			
Hyperactive/impulsive	0 (0.0)	19 (6.2)	-			
Combined	24 (66.7)	133 (43.3)	-			
NOS	1 (2.8)	16 (5.2)	-			
Comorbid diagnosis						
MDD	0 (0.0)	4 (1.3)	1 (0.8)	0.24	1.000‡	
SAD	0 (0.0)	7 (2.3)	0 (0.0)	2.81	0.219‡	
Social phobia	0 (0.0)	4 (1.3)	2 (1.6)	0.28	1.000‡	
Specific phobia	1 (2.8)	8 (2.6)	1 (0.8)	1.65	0.416‡	
Enuresis	0 (0.0)	5 (1.6)	0 (0.0)	1.73	0.433‡	
Tic disorder	3 (8.3)	31 (10.1)	3 (2.3)	7.52	0.023‡	A>C

Values are presented as mean±standard deviation or number (%). *ANOVA was used for analysis, and F was used as testing statistics; †chi-square test was used for analysis, and χ^2 was used as testing statistics; ‡Fisher's exact test was used for analysis. ADHD/ODD, ADHD with ODD; ADHD/noODD, ADHD without ODD; ADHD, attention-deficit/hyperactivity disorder; ODD, oppositional defiant disorder; NOS, not otherwise specified; MDD, major depressive disorder; SAD, separation anxiety disorder; ANOVA, analysis of variance

Symptoms and impairment profiles

The mean number of patients with inattention and hyperactivity-impulsivity symptoms was significantly higher in the ADHD/ODD and ADHD/noODD groups than that in the control group (F=670.23, p<0.001; F=343.46, p<0.001, respectively). The number of patients with inattention but not hyperactivity-impulsivity symptoms was significantly higher in the ADHD/ODD group than that in the ADHD/noODD group.

In all four settings, patients in the ADHD/ODD and ADHD/noODD groups exhibited ADHD symptoms more frequently than those in the control group. Specifically in the peer relationship domain, symptom presentation was significantly frequent in the ADHD/ODD group than that in the ADHD/noODD group; however, no significant differences were observed in the other three settings.

The ADHD groups differed significantly from the control group in all six domains of functional impairments (all p<0.001). Additionally, the ADHD/ODD and ADHD/noODD groups differed significantly in the domains of relationship with teachers, peer relationship, and self-esteem domains (Table 2).

Symptom rating scales

In ARS, inattention and hyperactivity-impulsivity were significantly higher in the two ADHD groups than those in the control group (F=215.37, p<0.001; F=171.46, p<0.001, respectively) as well as in the ADHD/ODD group than in the ADHD/noODD group, even after adjusting for age, sex, and presence of comorbid tic disorder.

In all five subscales of SRS, both ADHD groups exhibited higher scores than those of the control group (F=38.81, p<0.001; F=20.06, p<0.001; F=36.71, p<0.001; F=22.56, p<0.001; F=56.48, p<0.001, respectively), and the result remained the same after adjusting for age, sex, and comorbid tic disorder. In social communication and autistic mannerisms subscales, the ADHD/ODD group exhibited significantly higher scores than those of the ADHD/noODD group, after adjusting for age, sex, and comorbid tic disorder.

The P-GBI score was higher in both ADHD/ODD and ADHD/noODD groups than that in the control group, as well as in the ADHD/ODD group than that in the ADHD/noODD group (F=46.17, p<0.001) after adjusting for age, sex, and comorbid tic disorder.

In K-PRC, the anxiety, depression, delinquency, and psychosis subscale scores were higher in the ADHD/ODD group than those in the ADHD/noODD group (F=8.51, p<0.001; F=18.05, p<0.001; F=68.40, p<0.001; F=41.79, p<0.001, respectively). However, after adjusting for comorbid tic disorder, the

Table 2. Comparison of the number of symptoms, symptom presentations in four settings, and functional impairments in six domains among ADHD/ODD, ADHD/noODD, and control groups

	ADHD/ODD (OA, N=36)	ADHD/noODD (A, N=307)	Control (C, N=128)	F or χ^2	p	Post-hoc
Number of symptoms						
Inattention criteria	7.5±1.3	6.8±1.6	1.0±1.5	670.23	<0.001*	OA>A>C
Hyperactivity-impulsivity criteria	5.8±2.6	5.0±2.5	0.6±1.1	343.46	<0.001*	OA>C, A>C
Frequency of symptom presentations (N=466)						
At home	29 (80.6)	233 (76.4)	5 (4.0)	198.54	<0.001†	OA>C, A>C
At school	30 (83.3)	261 (85.6)	4 (3.2)	265.72	<0.001†	OA>C, A>C
In peer relationship	29 (80.6)	185 (60.7)	1 (0.8)	146.42	<0.001†	OA>A>C
In other activities	4 (11.1)	21 (6.9)	0 (0.0)	10.82	0.004†	OA>C, A>C
Functional impairments (N=466)						
Academic functioning	19 (52.8)	168 (55.1)	7 (5.6)	91.33	<0.001†	OA>C, A>C
Relationship with teachers	30 (83.3)	180 (59.0)	5 (4.0)	129.71	<0.001†	OA>A>C
Peer relationship	28 (77.8)	165 (54.1)	5 (4.0)	110.95	<0.001†	OA>C, A>C
Relationship with parents	26 (72.2)	195 (63.9)	9 (7.2)	122.34	<0.001†	OA>C, A>C
Participation in free-time activities	13 (36.1)	77 (25.2)	2 (1.6)	37.88	<0.001†	OA>C, A>C
Self-esteem	27 (75.0)	142 (46.6)	3 (2.4)	98.55	<0.001†	OA>A>C

Values are presented as mean±standard deviation or number (%). *ANOVA was used for analysis; †Fisher's exact test was used for analysis. ADHD/ODD, ADHD with ODD; ADHD/noODD, ADHD without ODD; ADHD, attention-deficit/hyperactivity disorder; ODD, oppositional defiant disorder; ANOVA, analysis of variance

ADHD/ODD and ADHD/noODD groups did not differ in the depression subscale score (Table 3).

Neuropsychological profiles

FSIQ scores differed significantly among the three groups, with both the ADHD/ODD and ADHD/noODD groups showing lower scores than those of the control group (F=24.55, p< 0.001). The results remained significant after adjusting for comorbid tic disorder. Other neuropsychological tasks were adjusted for FSIQ as well.

In the commission errors and response time variability subscales of the visual ATA, after adjusting for FSIQ and comorbid tic disorder, both the ADHD/ODD and ADHD/noODD groups scored significantly higher than the control group. The ADHD/ODD group had more errors than the ADHD/noODD group (F=16.42, p<0.001; F=10.21, p<0.001, respectively). In the commission errors and response time variability subscales of the auditory ATA, after adjusting for FSIQ and comorbid tic disorder, the scores were higher in both the ADHD groups than those in the control group (F=13.06, p< 0.001; F=7.33, p=0.001, respectively), and the commission errors score was significantly higher in the ADHD/ODD group than that in the ADHD/noODD group.

After adjusting for age, sex, FSIQ, and comorbid tic disorder, the ADHD/ODD and control groups differed significantly in the color-word score of SCWT (F=4.45, p=0.012) (Table 4).

DISCUSSION

We compared the clinical characteristics and neuropsychological profiles of children with ADHD with and without ODD and those of controls. The key findings of this study were that comorbid ODD in patients with ADHD led to greater symptom severity, functional impairment, and neuropsychological deficits than in those without ODD. Moreover, children with ADHD and ODD exhibited greater social impairments and emotional dysregulation than those without ODD. Although several studies have examined the impact of comorbid ODD on children and adolescents with ADHD, only a few have comprehensively examined the social, emotional, and cognitive aspects. Therefore, the findings of this study would contribute towards enhancing our understanding of the clinical characteristics of both ADHD and ODD.

In the present study, the ADHD/ODD group showed more inattention symptoms evaluated by clinicians and more inattention and hyperactivity-impulsivity symptoms reported by parents than the ADHD/noODD group. This result is consistent with the findings of the previous literature showing that children with ADHD and adolescents with ODD have more severe ADHD symptoms than those without ODD, suggesting that comorbid ODD may amplify both inattention and hyperactivity-impulsivity symptoms in children and adolescents with ADHD.[12,27] In a recent study, the ADHD with ODD

Table 3. Comparison of symptom rating scales among ADHD/ODD, ADHD/noODD, and control groups

	ADHD/ODD (OA, N=36)	ADHD/noODD (A, N=307)	Control (C, N=128)	ANOVA		ANCOVA*	
				p	Post-hoc	β (95% CI)	p
ARS (N=445)							
Inattention	15.7±5.6	12.1±5.4	3.7±3.3	<0.001	OA>A>C	3.525 (1.74, 5.31)	<0.001
Hyperactivity-impulsivity	13.6±7.1	9.5±5.3	2.7±2.6	<0.001	OA>A>C	3.962 (2.26, 5.67)	<0.001
SRS (N=397)							
Social awareness	54.8±10.6	51.7±10.2	42.8±7.8	<0.001	OA>C, A>C	3.336 (-0.29, 6.96)	<0.001
Social cognition	57.8±9.3	54.0±10.0	48.1±7.8	<0.001	OA>C, A>C	4.159 (-0.14, 7.68)	<0.001
Social communication	55.5±11.0	49.8±7.7	44.2±5.8	<0.001	OA>A>C	5.885 (3.04, 8.73)	<0.001
Social motivation	52.7±9.3	49.9±8.1	45.4±5.7	<0.001	OA>C, A>C	3.091 (-0.21, 5.97)	<0.001
Autistic mannerisms	59.0±13.4	53.2±9.3	46.0±4.7	<0.001	OA>C, A>C	5.937 (2.64, 9.23)	<0.001
P-GBI (N=394)	8.8±6.6	4.0±4.1	1.2±1.9	<0.001	OA>A>C	4.881 (3.41, 6.35)	<0.001
K-PRC (N=409)							
Verbal development	55.3±15.7	54.7±11.6	45.8±10.4	<0.001	OA>C, A>C	0.617 (-3.86, 5.10)	<0.001
Physical development	53.8±11.4	53.8±11.4	45.4±10.8	<0.001	OA>C, A>C	-0.039 (-4.38, 4.30)	<0.001
Anxiety	56.4±14.1	51.2±10.1	47.8±11.2	<0.001	OA>A>C	5.162 (1.02, 9.31)	<0.001
Depression	58.2±12.9	53.3±10.6	47.3±10.4	<0.001	OA>A>C	5.011 (-0.19, 9.14)	<0.001
Somatization	47.2±12.7	47.7±10.2	42.9±8.8	<0.001	OA>C, A>C	-0.596 (-3.33, 3.25)	0.001
Delinquency	67.3±14.6	57.9±11.4	45.3±10.4	<0.001	OA>A>C	9.357 (5.00, 13.72)	<0.001
Hyperactivity	66.1±14.6	62.4±11.4	45.0±10.2	<0.001	OA>C, A>C	3.746 (-0.60, 8.10)	<0.001
Family relationship	56.1±16.6	53.8±12.4	45.8±11.0	<0.001	OA>C, A>C	2.311 (-2.44, 7.07)	<0.001
Social relationship	52.4±11.3	49.8±9.9	46.3±10.4	0.001	OA>C, A>C	2.579 (-1.35, 6.49)	0.003
Psychosis	63.5±15.9	55.8±12.0	45.7±10.4	<0.001	OA>A>C	7.559 (3.00, 12.10)	<0.001

Values are presented as mean±standard deviation. *ANCOVA adjusted for age, sex, and presence of comorbid tic disorder. β: Beta coefficient between ADHD/ODD and ADHD/noODD. ADHD/ODD, ADHD with ODD; ADHD/noODD, ADHD without ODD; ADHD, attention-deficit/hyperactivity disorder; ODD, oppositional defiant disorder; ANOVA, analysis of variance; ANCOVA, analysis of covariance; CI, confidence intervals; ARS, ADHD Rating Scale; SRS, Social Responsiveness Scale; P-GBI, Parent General Behavior Inventory; K-PRC, Korean Personality Rating Scale for Children

group exhibited higher inattention and hyperactivity-impulsivity symptom severity reported by parents than the ADHD without ODD group.[12] Consistent with previous studies, the present results indicated that comorbid ODD additionally affects the symptom severity of children and adolescents with ADHD.

In our study, parents reported more hyperactivity-impulsivity symptoms in the ADHD/ODD group than those in the ADHD/noODD group. In contrast to the Western parents who tend to report mood symptoms in children and adolescents more effectively than the youth themselves,[28] the Korean parents may be less sensitive to their children's and adolescents' behavior.[29] Moreover, Korean parents focus more on children's externalizing behavior than on internalizing problems.[30] Thus, in our study, parents may have misconstrued their children's mood dysregulation to hyperactivity.

Another finding of this study was that functional impairments in social situation, such as relationship with teachers and peers, occurred more frequently in the ADHD/ODD group than in the ADHD/noODD group. This is consistent with the findings of previous literature showing that the presence of comorbid ODD in children and adolescents with ADHD leads to social dysfunction.[14-16] In a previous study,[15] children with ADHD and ODD displayed more negative behaviors and social problems while interacting with their peers, including bullying other kids, getting into fights, and being teased or bullied, than those without ODD. This could be considered the aggressive and impulsive characteristics of ODD contributing to problems in social situations. In another study,[16] children with ADHD and ODD experienced more difficulties in social problem-solving skills, such as interpreting social cues, evaluating responses, and selecting responses than those without ODD. Furthermore, in the present study, the ADHD/ODD group experienced more difficulties than those of the ADHD/noODD group in social abilities measured using SRS. In line with previous studies, the present study suggested that comorbid ODD in children with ADHD may contribute to increased severe social impairments related to social skill and aggres-

Table 4. Comparison of the FSIQ, ATA, CCTT, and Stroop test among the ADHD/ODD, ADHD/noODD, and control groups

	ADHD/ODD (OA, N=36)	ADHD/noODD (A, N=307)	Control (C, N=128)	ANOVA		ANCOVA*			
				p	Post-hoc	β1 (95% CI)	β2 (95% CI)	β3 (95% CI)	p
FSIQ (N=454)	99.0±15.2	97.9±15.4	108.2±12.9	<0.001	C>OA, C>A	-8.994 (-14.69, -3.30)	-10.046 (-13.41, -6.69)	1.052 (-4.09, 6.19)	<0.001
ATA, visual (N=461)									
Omission errors	3.8±4.1	3.4±5.2	1.3±4.3	<0.001	OA>C, A>C	1.693 (-0.26, 3.45)	1.081 (-0.04, 2.21)	0.512 (-1.15, 2.17)	0.038
Commission errors	5.2±5.2	2.9±3.6	1.0±2.2	<0.001	OA>A>C	3.181 (1.89, 4.47)	0.803 (0.02, 1.59)	2.378 (1.23, 3.53)	<0.001
Response time	0.5±2.0	0.7±1.6	0.8±1.3	0.421		-0.244 (-0.85, 0.37)	-0.017 (-0.39, 0.35)	-0.226 (-0.77, 0.31)	0.472
Response time variability	3.3±3.5	1.9±2.5	0.8±2.5	<0.001	OA>C, A>C	1.921 (0.94, 2.91)	0.509 (0.09, 1.12)	1.411 (0.53, 2.30)	<0.001
ATA, auditory									
Omission errors	2.4±4.9	1.4±3.6	0.4±1.8	<0.001	OA>C, A>C	1.905 (0.66, 3.15)	0.994 (-0.25, 1.74)	0.911 (-0.20, 2.02)	0.046
Commission errors	2.8±3.2	1.6±2.4	0.2±1.6	<0.001	OA>C, A>C	1.993 (1.14, 2.84)	0.742 (0.23, 1.25)	1.251 (0.49, 2.01)	<0.001
Response time	-0.5±1.4	-0.6±1.4	0.1±0.9	<0.001	A>C	-0.224 (-0.71, 0.27)	-0.284 (0.58, 0.01)	0.060 (-0.38, 0.50)	0.003
Response time variability	0.4±1.5	0.1±1.2	-0.4±0.9	<0.001	OA>C, A>C	0.747 (0.31, 1.12)	0.401 (0.14, 0.67)	0.347 (-0.05, 0.74)	0.001
CCTT (N=380)									
CCTT1	48.1±8.0	48.1±11.1	51.7±10.8	0.015	A>C	-1.811 (-0.65, 2.86)	-1.675 (-4.30, 0.95)	-0.136 (-4.37, 4.10)	0.442
CCTT2	47.0±12.5	47.7±11.0	53.1±10.4	<0.001	OA>C, A>C	-4.348 (-8.88, 0.19)	-3.253 (-5.81, -0.70)	-1.095 (-5.26, 3.07)	0.030
Interference score	48.0±12.2	48.8±10.8	53.0±9.9	0.002	A>C	-3.890 (-8.48, 0.70)	-2.895 (-5.47, -0.32)	-0.995 (-5.21, 3.22)	0.064
Stroop test (N=356)									
Word score	45.8±11.1	41.2±12.1	45.3±11.5	0.005	A>C	4.425 (-0.43, 9.28)	-0.199 (-2.98, 2.58)	4.624 (-0.19, 9.05)	0.121
Color score	41.9±13.9	44.2±12.5	48.6±10.9	0.003	OA>C, A>C	-4.495 (-9.64, 0.65)	-2.268 (-5.22, 0.68)	-2.227 (-6.93, 2.47)	0.160
Color-word score	39.4±12.2	42.7±12.3	49.0±11.2	<0.001	OA>C, A>C	-6.774 (-11.82, -1.73)	-3.511 (-6.40, -0.62)	-3.263 (-7.87, 1.34)	0.012
Interference score	47.9±16.4	50.3±12.7	50.2±12.1	0.667		-2.417 (-8.25, 3.42)	0.130 (-3.21, 3.47)	-2.546 (-7.87, 2.78)	0.641

Values are presented as mean±standard deviation. β1: Beta coefficient between ADHD/ODD and control. β2: Beta coefficient between ADHD/noODD and control. β3: Beta coefficient between ADHD/ODD and ADHD/noODD. *ANCOVA adjusted for age, sex, FSIQ, and presence of tic disorder. FSIQ, Full-Scale Intelligence Quotient; ATA, Advanced Test of Attention; CCTT, Children's Color Trails Test; ADHD/ODD, ADHD with ODD; ADHD/noODD, ADHD without ODD; ADHD, attention-deficit/hyperactivity disorder; ODD, oppositional defiant disorder; ANOVA, analysis of variance; ANCOVA, analysis of covariance; CI, confidence intervals

sive and impulsive characteristics of ODD.

In the present study, the ADHD/ODD group displayed high anxiety and depression subscale scores in K-PRC and high P-GBI scores than those of the ADHD/noODD group. Children with ODD are reported to have significant deficiencies in handling emotions and experience emotional dysregulation.[31] In addition, previous studies have demonstrated that symptoms of irritability and the negative effect dimension of ODD are related to depressive symptoms,[32-36] suggesting that the irritable dimension of ODD is associated with depressive symptoms. Humphreys et al.[37] reported that high anxiety and depression in the ADHD/ODD group results from the characteristics of comorbid ODD. Moreover, Park et al.'s[38] study indicated that long-term methylphenidate use of >1 year can decrease the risk of depression, conduct disorders, and ODD. Thus, the results of the present study suggested that children with ADHD and ODD experience more mood dysregulation than children without ODD.

In the present study, more commission errors in the visual and auditory ATAs occurred in the ADHD/ODD group than it did in the ADHD/noODD group. Commission errors are counted when the child responds to a stimulus that was not a target and measures impulsivity, self-regulation, and inhibitory control of executive functioning.[39-41] Therefore, the higher score in the ADHD/ODD group than that in the ADHD/noODD group suggests the increased difficulty in inhibitory control. Low inhibitory control, which leads to impulsive behaviors, tends to negatively influence peer preference.[42] In the present study, response time variability in the visual ATA was significantly higher in the ADHD/ODD group than that in the ADHD/noODD group. It reflected sustained attention, and high response time variability implies that the response time was unstable, which indicates the presence of occasional lapses in attention, thereby indicating a deficit in sustained attention.[43] In the present study, the inhibitory control and sustained attention of children and adolescents with ADHD were negatively influenced by comorbid ODD.

Two broad models explain the high comorbidity of ADHD and ODD, the developmental precursors and correlated risk factors models.[44] The developmental precursors model suggests that symptoms of ADHD may lead to the development of ODD since the patients are exposed to negative parenting practices, family stress, and peer rejection.[45] The correlated risk factors model posits that comorbidities may be associated with correlated or shared risk factors.[46] The present findings of the ADHD/ODD group displaying more frequent symptoms, functional and social impairments, and lack of neuropsychological ability may be related to the developmental precursors model. Thus, ADHD may have played the role of a developmental precursor of ODD, which may have accounted for the severe symptomatology of the ADHD/ODD group compared to the ADHD/noODD group. However, the present study was limited to understanding the mechanism clearly; therefore, a prospective cohort study is further required to examine comorbid ADHD and ODD.

This study had several limitations. First, all three groups were recruited from an outpatient clinic of a single hospital; therefore, the results may not be generalizable to all children with ADHD with or without ODD. Second, no ODD-only group was included. Comparison with this group is required to further clarify the features uniquely evident in children with ODD only compared to other groups. Third, the number of patients in the ADHD/ODD group was small; therefore, the results may alter when a larger sample size is used. We could not stratify the sample further by sex, age, or ADHD subtype because of its small size. To enhance the sample size for future studies, multicenter cooperation will be required. Fourth, the groups differed significantly in sex distribution and the presence of comorbid tic disorder, despite the adjustments made for these relevant factors. Fifth, as our study participants were relatively young, with an average age of 7 to 8 years, we were unable to examine the impact of any accompanying conduct disorder.

Despite these limitations, the present study had the following advantages: 1) standardized instruments were used to diagnose ADHD and ODD; 2) neuropsychological examination and rating scales were applied to assess multiple domains comprehensively, including social skills, emotional regulation, intelligence, and cognitive functions; and 3) the participants were Asians and not from the Western population.

In conclusion, the present study suggested that the presence of comorbid ODD in children with ADHD leads to elevated levels of symptomatology, functional and social impairments, and neuropsychological deficits. Future research should focus on clarifying the relationship between ADHD and ODD and defining the influence of comorbid ODD on children with ADHD.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Haewon Kim, Taeyeop Lee, Hyo-Won Kim. Data curation: Haewon Kim, Taeyeop Lee, Hyo-Won Kim. Formal analysis: Haewon Kim, Taeyeop Lee, Seonok Kim, Hyo-Won Kim. Statistics: Seonok Kim. Investigation: Taeyeop Lee, Hyo-Won Kim. Methodology: Taeyeop Lee, Hyo-Won Kim. Project administration: Hyo-Won Kim. Supervision: Eunji Jung, Taeyeop Lee, Hyo-Won Kim. Writing—original draft: all authors. Writing—review & editing: all authors.

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