Original Article

Neuropsychological Profile Related with Executive Function of Chinese Preschoolers with Attention-Deficit/Hyperactivity Disorder: Neuropsychological Measures and Behavior Rating Scale of Executive Function-Preschool Version

Hui-Feng Zhang[1,2], Lan Shuai[1,2], Jin-Song Zhang[1,2], Yu-Feng Wang[3], Teng-Fei Lu[1,2], Xin Tan[1,2], Jing-Xue Pan[1,2], Li-Xiao Shen[2,4]

[1]Department of Medical Psychology, Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai 200092, China
[2]Ministry of Education and Shanghai Key Laboratory of Children's Environment Health, Shanghai 200092, China
[3]Department of Child Psychiatry Research, Peking University Sixth Hospital, Peking University Institute of Mental Health, Key Laboratory of Mental Health, Ministry of Health (Peking University), Beijing 100191, China
[4]Department of Developmental Behavioral and Child Healthcare, Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai 200092, China

Abstract

Background: Previous studies have found that schoolchildren with attention-deficit/hyperactivity disorder (ADHD) showed difficulties in neuropsychological function. This study aimed to assess neuropsychological function in Chinese preschoolers with ADHD using broad neuropsychological measures and rating scales and to test whether the pattern and severity of neuropsychological weakness differed among ADHD presentations in preschool children.
Methods: The 226 preschoolers (163 with ADHD and 63 controls) with the age of 4–5 years were included and assessed using the Behavior Rating Scale of Executive Function-Preschool Version (BRIEF-P) and a series of tests to investigate neuropsychological function.
Results: Preschoolers with ADHD showed higher scores in all domains of the BRIEF-P (inhibition: 30.64 ± 5.78 vs.20.69 ± 3.86, $P < 0.001$; shift: 13.40 ± 3.03 vs.12.41 ± 2.79, $P = 0.039$; emotional control:15.10 ± 3.53 vs.12.20 ± 2.46, $P < 0.001$; working memory: 28.41 ± 4.99 vs.20.95 ± 4.60, $P < 0.001$; plan/organize: 17.04 ± 3.30 vs.13.29 ± 2.40, $P < 0.001$) and lower scores of Statue (23.18 ± 7.84 vs.28.27 ± 3.18, $P = 0.001$), Word Generation (15.22 ± 6.52 vs.19.53 ± 7.69, $P = 0.025$), Comprehension of Instructions (14.00 ± 4.44 vs.17.02 ± 3.39, $P = 0.016$), Visuomotor Precision ($P < 0.050$), Toy delay ($P = 0.048$), and Matrices tasks ($P = 0.011$), compared with normal control. In terms of the differences among ADHD subtypes, all ADHD presentations had higher scores in several domains of the BRIEF-P ($P < 0.001$), and the ADHD-combined symptoms (ADHD-C) group had the poorest ratings on inhibition and the ability to Plan/Organize. For neuropsychological measures, the results suggested that the ADHD-C group had poorer performances than the ADHD-predominantly inattentive symptoms (ADHD-I) group on Statue tasks ($F = 7.34$, $\eta^2 = 0.12$, $P < 0.001$). Furthermore, the ADHD-hyperactive/impulsive symptoms group had significantly poorer performances compared to the ADHD-C group in the Block Construction task ($F = 4.89$, $\eta^2 = 0.067$, $P = 0.003$). However, no significant group differences were found between the ADHD-I group and normal control.
Conclusion: Based on the combined evaluation of performance-based neuropsychological tests and the BRIEF-P, preschoolers with ADHD show difficulties of neuropsychological function in many aspects.

Key words: Attention-Deficit/Hyperactivity Disorder; Behavior Rating Scale of Executive Function-Preschool Version; Chinese Preschoolers; Neuropsychological Function

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder characterized by age-inappropriate displays of inattention, hyperactivity, and impulsivity that typically emerge during the preschool

Access this article online
Quick Response Code:
Website: www.cmj.org
DOI: 10.4103/0366-6999.226893

Address for correspondence: Dr. Jin-Song Zhang, Department of Medical Psychology, Xinhua Hospital Affiliated to Shanghai Jiao Tong University, 1665 Kongjiang Road, Shanghai 200092, China
E-Mail: zhangjinsong@xinhuamed.com.cn

Received: 13-11-2017 **Edited by:** Xin Chen
How to cite this article: Zhang HF, Shuai L, Zhang JS, Wang YF, Lu TF, Tan X, Pan JX, Shen LX. Neuropsychological Profile Related with Executive Function of Chinese Preschoolers with Attention-Deficit/Hyperactivity Disorder: Neuropsychological Measures and Behavior Rating Scale of Executive Function-Preschool Version. Chin Med J 2018;131:648-56.

years and often continue into adulthood, with significant functional disability throughout the lifespan.[1] According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), ADHD is specified as three different presentations: predominantly inattentive symptoms (ADHD-I), predominantly hyperactive/impulsive symptoms (ADHD-HI), and combined symptoms (ADHD-C). Considerable research has suggested that schoolchildren with ADHD showed difficulties in neuropsychological domains including executive function (EF) and non-EF in response inhibition, working memory, planning, delay aversion, expressive language, and sustained attention.[2-4] However, few researches have examined whether neuropsychological weakness demonstrates different styles in the ADHD presentations identified early in the preschool period.

There are two ways to assess neuropsychological function in the preschool period: cognition performance-based tests[5,6] and rating scales.[7] The Behavior Rating Scale of Executive Function-Preschool Version (BRIEF-P) is used to assess the components of EF in preschool children and can identify behavioral difficulties in working memory and inhibition.[7] In terms of cognition performance-based tests, NEPSY Second Edition (NEPSY-II) is a comprehensive instrument used to assess neuropsychological development including attention and EF, memory and learning, social perception, language, sensorimotor skills, and visuospatial processing.[8] Rating scales are primarily based on parents' and teachers' reports of the children's performance in daily life, whereas performance-based tests are administered by trained examiners under structured conditions. Low or no significant correlations have been found between performance-based tests and rating scales.[9,10] Performance-based tests assess the ability of processing efficiency in highly standardized laboratory conditions, whereas rating scales measure individual goal pursuits in daily life.[9-13] Performance-based tests and rating scales provide important and adequate assessments of various aspects of cognitive and behavioral functioning. Therefore, this study adopted the BRIEF-P and related tasks in NEPSY-II to identify preschoolers with ADHD who might have problems with EF.

Given all of these considerations, we used broad neuropsychological measures related with EF and age-appropriate rating scales of EF to test the hypothesis that Chinese preschool children with ADHD have poorer performance in neuropsychological functions on EF and related abilities compared to normally developed peers. We also examined whether the pattern and severity of EF weakness differ among ADHD presentations in Chinese preschool children.

Methods

Ethical approval

The study was conducted in accordance with the *Declaration of Helsinki* and was approved by the Ethics Committee of Xinhua Hospital Affiliated to Shanghai Jiao Tong University (approval number: XHEC-C-2014-082). School agreement and parental written informed consent were obtained before participation in the study. All preschoolers' parent signed their names on the informed consent paper.

Participants

One hundred and sixty-three children (age ranged from 4 years to 5 years and 11 months) were included in the ADHD group, with subgroups of ADHD-I (n = 25), ADHD-HI (n = 44), and ADHD-C (n = 94). The children were recruited at the Outpatient Clinic in the Department of Medical Psychology, Xinhua Hospital Affiliated to Shanghai Jiao Tong University, from May 2014 to August 2016. The clinical interviews and diagnoses were made by psychiatrists based on the DSM-5 criteria. The parents were also interviewed with the Diagnostic Infant and Preschool Assessment (DIPA)[14] during the psychological assessment. Children included in the ADHD group were required to meet the following inclusion requirements: (1) meet both the criteria of ADHD based on the interview by the DIPA and clinical diagnosis with DSM-5; (2) Full-Scale Intelligence Quotient (FSIQ) estimated by the Wechsler Primary and Preschool Scale of Intelligence (WPPSI) not <80; (3) parents volunteered to participate in this study; (4) no other severe mental disorder or physical disease that might interfere with the assessment and result, such as ASD, schizophrenia, epilepsy, traumatic, or brain injury; (5) no history of medication treatment at least 1 week before administration of the tests; and (6) no medication intervention for ADHD symptoms before assessment.

The normal control (NC) group consisted of 63 healthy children with the same age span who were recruited from two local kindergartens in Shanghai. The control group did not meet the criteria of ADHD based on the interview by DIPA. The other inclusion criteria were the same as the requirements for the ADHD children. All of the participants were native Chinese speakers, and all of the measures were Chinese versions.

Diagnostic interview

The DIPA (version 2/28/14) is a semi-structured clinical interview developed for children under 6 years of age based on the DSM-4 and updated according to DSM-5.[14] The DIPA includes 14 disorder modules: posttraumatic stress disorder, major depressive disorder, bipolar I disorder, ADHD, oppositional defiant disorder, conduct problem, separation anxiety disorder, agoraphobia, specific phobia, general anxiety disorder, obsessive-compulsive disorder, reactive attachment disorder, and sleep disorder. The ADHD module includes all 18 symptoms of the DSM-4 criteria for ADHD. Parents describe the emergence, frequency, and severity of ADHD symptoms in two or more settings (e.g., home, school, or public; with friends or relatives; and in other activities) for the previous 6 months. The interviewer then rates these descriptions. The DIPA has been demonstrated to be a reliable and valid measure in research and clinical work.

Intelligence assessment

General intellectual ability was measured by the WPPSI, which was constructed by Wechsler to assess the intelligence of children aged 4–6 years. Standardized quotients are presented: verbal IQ, performance IQ, and FSIQ. The original version of the WPPSI was translated into Chinese, with modifications to suit the Chinese culture and context.[15]

Assessment of executive function and related neuropsychological abilities

The BRIEF-P is a 63-item questionnaire for parents and teachers to assess the components of EF in preschool children aged 2–5 years.[16] Items are rated 1 (never), 2 (sometimes), or 3 (often). All raw scales were transformed into standardized scores for interpretation. The measure extracts five empirically derived clinical scales: inhibition, shifting, working memory, emotional control, and planning/organizing. These subscales were developed for three broader indices (the Flexibility Index [FI], the Inhibitory Self-Control Index, and the emergent metacognition index [EMI]) and a composite score, the Global Executive Composite (GEC). The BRIEF-P has shown high concurrent and discriminant validity and adequate reliability in Chinese children: its retest reliability was 0.54–0.72, and the Cronbach's α coefficient was 0.78–0.95.[17]

Neuropsychological measures on executive function and related psychological abilities

Several cognition performance-based tests were included. Nine subtests from six domains of the NEPSY-II, one subtest from the Differential Ability Scales Second Edition (DAS-II), and one test of gratification delay were included in this study.

NEPSY-II is a comprehensive instrument designed to assess neuropsychological development.[8] It consists of a series of neuropsychological subtests from six domains of performance: attention and EF, memory and learning, social perception, language, sensorimotor skills, and visuospatial processing. In this study, nine age-appropriate NEPSY-II subtests related to EF were chosen, which included Memory-for-Designs (MD), Narrative Memory (NM), Statue, Affect Recognition (AR), Theory of Mind (TM), Word Generation (WG), Comprehension of Instructions (CIs), Block Construction (BC), and Visuomotor Precision (VP).

The MD task, which belongs to the memory and learning domain, was conducted to assess short-term visual detail and visuospatial memory. In the MD task, the participating child was shown a grid with four to eight cards on a page, which was covered after 10 s. The child was then asked to select the same cards from several distractor cards and place the cards in a grid in the same location as previously shown. In total, the MD task consisted of four different trials of increasing complexity. The content raw score, the spatial raw score, and the bonus raw score were recorded. The total raw score is the sum of the content, spatial, and bonus raw scores.

The NM task, which also belongs to the memory and learning domain, was conducted to evaluate memory for organized verbal material. The participating child listened to an age-appropriate story and was then required to recall the story. The child was subsequently asked to answer questions about the missing details from the story. In the cued recall and recognition conditions, a correct response = 1 and an incorrect response = 0. In the free recall condition, a correct response = 2 and an incorrect response = 0.

The Statue task, which belongs to the attention and EF domain, was conducted to assess motor persistence and inhibition. The participating child was required to close his or her eyes and maintain a body position for 75 s. The child was not allowed to move in response to sound distracters during the administration. The researcher made noise, such as knocking on the table twice, to disturb the child's performance at designated times. Body movements, eye openings, and vocalizations were regarded as errors.

The AR task, which belongs to the social perception domain, was used to evaluate the ability to understand a physical expression that serves as an indicator of emotion (e.g., happy, neutral, and sad). We selected three age-appropriate tasks from the original four tasks. For the first task, the participating child was asked whether two photographs of faces showed the same facial expression. In the second task, he or she was asked to choose two similar facial expression from three or four photographs. For the third task, the participant was asked to select one of four faces that depicted the same effect as a face at the top of the page. The researcher ensured that age-appropriate start points and stop points were used during the administration. The AR total score was calculated, with one point given for a correct response and zero point for an incorrect response.

The TM task, which belongs to the social perception domain, was used to assess the ability to understand mental functions and another's point of view. The TM tasks included two tests: the verbal test and the contextual test. In the verbal subtask, the participating child was required to interpret another's thoughts, ideas, and feelings. In the contextual subtask, the child was asked to select one of four faces in a social context. The researcher recorded the child's response. One point was given for a correct response and zero point for an incorrect response.

The WG task, which belongs to the language domain, was used to assess the ability of verbal productivity. The participating child was required to generate as many as words as possible in 60 s that were related to animal, food, or beverage categories. A noncategory or nonsense word was regarded as an incorrect response. A category word was considered a correct response. The WG total score was the sum of the correct words.

The CIs task, which also belongs to language, was used to assess the ability to perceive, process, and execute oral instructions. The participating child was required to select appropriate shapes according to the researcher's oral instructions. An item that met all of the oral instructions (e.g., order, sequence) was regarded as a correct response. The CI total score was the sum of the item scores.

The BC task, which belongs to the visuospatial processing domain, was used to assess visuomotor and visuospatial ability. The participating child was required to rebuild a BC according to models or two-dimensional photographs on a page within the time limit. The item score was determined by the completion time and correct assembly. The BC total score was the sum of the item scores.

The VP, which belongs to the sensorimotor domain, was used to assess graphomotor speed and accuracy. The participating child was required to draw lines inside of a track as quickly as possible. The VP task included mouse, train, car, and motorcycle tracks. The researcher recorded the total completion time, the total error numbers, and the total number of times the child lifted the pencil from the paper.

The DAS-II is a comprehensive instrument to assess the cognition abilities of individuals from ages 2 years 6 months to 17 years 11 months.[18] Metrics and delay of gratification were chosen to assess the reasoning ability and self-control, respectively.

The Matrices test was performed to assess nonverbal reasoning ability; namely, perception and the application of relationships among abstract figures. The participating child was shown an incomplete matrix and was then required to point to one appropriate figure from four or six choices. The researcher ensured that age-appropriate start points and stop points were utilized during test administration. One point was given for a correct response and zero point for an incorrect response.

Delay of gratification tasks measures self-control ability.[19] These tasks consist of a Candy Delay Task and a toy delay task. The participating children were shown a transparent box that contained some toys or candy and were told that they could not play with the toys or eat the candy until the experimenter rang the bell. The experimenter rang the bell in 30 s or 60 s and scored the child according to his or her performance.

Procedure

The recruitment process involved three stages. In first stage, school approval and parental written informed consent were obtained in kindergartens. The medical history was primarily reported by their teachers and parents excluded the abnormal children with obviously medical and developmental problems. The case children and their parents were interviewed in clinic, and primary diagnoses were made by psychiatrists according to comprehensive history taking and psychiatric examination. Informed consent was obtained before taking further assessments. In the second stage, the participants completed the assessments mentioned above. Trained master's students individually administered all of the tasks. All tasks took approximately 40–50 min. During this period, the children could take a break for 5–10 min if getting tired. Meanwhile, parents completed questionnaires and received the interview with DIPA. In the third stage, the children and their parents were interviewed by senior psychiatrists again with all the completed reports, and the final diagnosis was made according to DSM-5. Preschoolers with ADHD who met the including criteria were recruited in this study.

Statistical analysis

The statistical analyses were performed with SPSS Statistics version 23 (IBM; Armonk, New York, USA) and EpiData 3.1 (The EpiData Association, Odense, Denmark). The data were shown as mean ± standard deviation (SD) or median (interquartile range). First, we compared neuropsychological difference in preschool children with ADHD to the NC group using a multivariate analysis of covariance (MANCOVA), in which IQ and age were performed as covariates. Second, a MANCOVA was conducted to assess the differences among ADHD subtypes and NC groups while controlling for IQ and age. We also used Bonferroni group comparisons to investigate pairwise comparisons between any two groups. A $P < 0.05$ was considered statistically significant.

Results

Demographics

There were no significant differences neither by age (59.1 ± 7.2 months vs. 59.7 ± 5.3 months, $P = 0.364$) nor gender (boy:girl, 134:29 vs. 45:18, $P = 0.065$) between ADHD and NC groups. However, there were significant differences on FSIQ (104.63 ± 17.88 vs. 114.98 ± 12.60, $P = 0.031$) between the ADHD and NC groups. In terms of parents' educational level, there were significant differences in education period of the father (14.8 ± 3.0 years vs. 16.10 ± 2.38, $P = 0.021$), mother (14.5 ± 3.2 years vs. 15.9 ± 2.2 years, $P = 0.035$), and main caregiver (12.6 ± 3.6 years vs. 14.4 ± 3.3 years, $P = 0.023$) between the ADHD and NC groups.

Comparison of the executive function Dimensions with Behavior Rating Scale of Executive Function-Preschool Version

Compared to the NC group, the ADHD group had significantly higher scores in all dimensions of the BRIEF-P (F [1, 236] = 3.86–137.32, $\eta^2 = 0.02–0.40$, $P < 0.05$; Table 1).

The results of the data analyses are presented in Table 2. There were significant group differences in the subscales of Inhibition and Inhibition Self-Control Index (F [3, 236] = 45.30–57.03, $\eta^2 = 0.41–0.46$, $P < 0.001$). The results showed that all ADHD subtypes had higher scores on Inhibition and Inhibition Self-Control Index compared to the NC group, and the ADHD-C subtype had the highest scores. Compared to ADHD-I subtype, ADHD-HI subtype had poorer performance on Inhibition and Inhibition Self-control. Compared to NCs, all ADHD subtypes also showed poorer working memory (F [3, 236] = 33.54, $\eta^2 = 0.33$, $P < 0.001$) and increased scores on the EMI (F [3, 236] = 34.82, $\eta^2 = 0.36$, $P < 0.001$). The results also indicated that ADHD-C subtype had significantly higher scores in working memory and EMI than ADHD-HI subtype. As to the Shift, ADHD-C subtype had significantly increased scores compared to the NC group (F [3, 236] = 2.28, η^2 = 0.04, P = 0.039). However, the results suggested that, in terms of shift, ADHD-I and ADHD-HI subtypes did not differ from the NC group, and that there was no significant difference among the ADHD subtypes. Compared to NC group, ADHD-HI and ADHD-C subtypes had more difficulties with emotional control (F [3, 236] = 11.64, η^2 = 0.15, P < 0.001). Data analyses revealed that ADHD-C and ADHD-HI subtype had significantly higher scores on the FI than NC group (F [3, 236] = 7.62, η^2 = 0.11, P < 0.001), indicating greater difficulty in cognition flexibility for the two ADHD subtypes. There was a significant difference on the ability to Plan/Organize and GEC (F [3, 236] = 27.18–40.30, η^2 = 0.27–0.39, P < 0.001): all ADHD subtypes showed significantly higher scores on the ability to Plan/Organize and GEC than the NC group; compared to ADHD-I and ADHD-HI subtypes, ADHD-C subtype had significantly increased scores on the ability to Plan/Organize and GEC.

Comparison using neuropsychological test batteries

As shown in Table 3, ADHD group had significantly lower scores on the Statue, WG, CI, VP, Toy Delay Task, and Matrices Tasks than NC children (F [1, 236] = 5.12–11.38, η^2 = 0.05–0.10, P < 0.050), implying poorer performance. Compared to NC children, ADHD group only showed significantly lower content scores on Memory Delay tasks (F [1, 236] =4.82, η^2 = 0.04, P = 0.048). No significant differences were found on NM tasks, AR tasks, TM tasks, Candy Delay Tasks, and Block Structure tasks between ADHD and NC groups [Table 3].

As shown in Table 4, there were significant group differences on the Statue task (F [3, 236] = 7.34, η^2 = 0.12, P < 0.001). The ADHD-C and ADHD-HI subtypes had significantly poorer performances on Statue task compared to NC group (P < 0.050). Compared to the ADHD-I subtype, the ADHD-C subtype had significantly lower scores (P = 0.032), implying poorer performance.

On the WG task, ADHD-C subtype displayed significantly decreased scores compared to NC groups (F [3, 236] = 5.93, η^2 = 0.09, P = 0.018). The ADHD-HI and ADHD-I subtypes did not differ significantly from NC group or from one another.

With regard to the delay of gratification tasks, the results revealed that ADHD-HI subtype had significantly lower scores on toy delay than NC group (F [3, 236] = 2.57, η^2 = 0.05, P = 0.046). However, no significant group effects were found on the Candy Delay Task.

On the visuomtor precision tasks, ADHD-HI subtype had significantly fewer total time than NC group

Table 1: Executive Function of the ADHD and NC groups on the BRIEF-P

Subscales	ADHD group (n = 163)	NC group (n = 63)	η^2	P
Inhibition	30.64 ± 5.78	20.69 ± 3.86	0.40	<0.001
Shift	13.40 ± 3.03	12.41 ± 2.79	0.02	0.039
Emotional control	15.10 ± 3.53	12.20 ± 2.46	0.13	<0.001
Working memory	28.41 ± 4.99	20.95 ± 4.60	0.28	<0.001
Plan/organize	17.04 ± 3.30	13.29 ± 2.40	0.20	<0.001
ISCI	45.74 ± 8.25	32.90 ± 5.73	0.35	<0.001
FI	28.50 ± 5.88	24.61 ± 4.46	0.09	<0.001
EMI	45.45 ± 7.75	34.24 ± 6.61	0.28	<0.001
GEC	104.59 ± 16.26	79.54 ± 12.75	0.32	<0.001

The data are shown as mean ± SD. BRIEF-P: Behavior Rating Scale of Executive Function-Preschool Version; ADHD: Attention-deficit/hyperactivity disorder; NCs: Normal controls; ISCI: Inhibition Self-Control Index; FI: Flexibility Index; EMI: Emergent Metacognition Index; GEC: Global Executive Composite; SD: Standard deviation.

Table 2: Executive function of ADHD subtypes and NC group on the BRIEF-P

Subscales	ADHD subtypes			NC group (n = 63, d)	η^2	Bonferroni group comparison (P<0.050)
	ADHD-I (n = 25, a)	ADHD-HI (n = 44, b)	ADHD-C (n = 94, c)			
Inhibition	25.74 ± 4.68	29.93 ± 5.82	31.96 ± 5.41	20.69 ± 3.86	0.46	c, b > a > d
Shift	13.00 ± 3.04	12.84 ± 2.41	13.74 ± 3.26	12.41 ± 2.79	0.04	c > d
Emotional control	13.74 ± 3.38	14.86 ± 3.25	15.49 ± 3.65	12.20 ± 2.46	0.15	b, c > d
Working memory	28.53 ± 4.64	26.32 ± 5.55	29.36 ± 4.51	20.95 ± 4.60	0.33	a, b, c > d; c > b
Plan/organize	15.95 ± 3.41	15.68 ± 3.06	17.90 ± 3.14	13.29 ± 2.40	0.27	a, b, c > d; c > b
ISCI	39.47 ± 7.14	44.80 ± 8.34	47.45 ± 7.79	32.90 ± 5.73	0.41	c >b > a > d
FI	26.74 ± 5.92	27.70 ± 4.97	29.23 ± 6.20	24.61 ± 4.46	0.11	b, c > d
EMI	44.47 ± 7.60	42.00 ± 8.19	47.27 ± 7.03	34.24 ± 6.61	0.36	a, b, c > d; c > b
GEC	96.95 ± 15.74	99.64 ± 16.95	108.46 ± 14.96	79.54 ± 12.75	0.39	c > a, b > d

The data are shown as mean ± SD. BRIEF-P: Behavior Rating Scale of Executive Function-Preschool Version; ADHD: Attention-deficit/hyperactivity disorder; NC: Normal control; ISCI: Inhibition Self-Control Index; FI: Flexibility Index; EMI: Emergent Metacognition Index; GEC: Global Executive Composite; SD: Standard deviation; ADHD-I: ADHD-inattentive; ADHD-HI: ADHD-hyperactive/impulsive; ADHD-C: ADHD-combined.

Table 3: Neuropsychological profiles of the ADHD and NC groups on NEPSY-II

EF tests	ADHD group (n = 163)	NC group (n = 63)	η^2	P
MD				
MDC	29.55 ± 6.59	32.64 ± 7.84	0.04	0.048
MDS	14.82 ± 4.85	16.42 ± 4.72	0.02	>0.050
MDT	56.03 ± 19.27	61.73 ± 21.39	0.02	>0.050
NM				
NMFC	9.00 (10.00)	11.00 (6.00)	0.01	>0.050
NMRG	9.92 ± 2.83	10.97 ± 2.62	0.03	>0.050
Statue	23.18 ± 7.84	28.27 ± 3.18	0.10	0.001
AR	12.66 ± 4.28	14.19 ± 3.19	0.03	>0.050
TM	10.36 ± 4.46	12.00 ± 4.95	0.03	>0.050
WG	15.22 ± 6.52	19.53 ± 7.69	0.08	0.025
CI	14.00 ± 4.44	17.02 ± 3.39	0.10	0.016
BC	8.86 ± 2.97	10.05 ± 2.38	0.04	>0.050
VP				
VPTT	99.50 (31.25)	121.00 (70.00)	0.07	0.006
VPTE	94.50 (70.00)	72.00 (71.00)	0.06	0.007
VPPL	1.00 (3.25)	2.00 (8.00)	0.05	0.018
DG				
CDs	6.83 ± 0.71	6.95 ± 0.29	0.01	>0.050
CDt	2.74 ± 0.52	2.83 ± 0.42	0.01	>0.050
TD	2.00 (1.00)	2.00 (3.00)	0.04	0.048
Matrices	7.00 (3.00)	8.00 (4.00)	0.07	0.011

The data are shown as mean ± SD or median (IQR). ADHD: Attention-deficit/hyperactivity disorder; NC: Normal control; MD: Memory-for-designs; MDC: Memory-for-designs content; MDT: Memory-for-designs total; NM: Narrative memory; NMFC: Narrative memory free cued recall; AR: Affect recognition; TM: Theory of mind; WG: Word generation; CI: Comprehension of instructions; BC: Block construction; VP: Visuomotor precision; VPTT: Visuomotor precision total time; VPTE: Visuomotor precision total error; VPPL: Visuomotor precision pencil lift total; DG: Delay of gratifications; CDs: Candy delay seven scores; CDt: Candy delay three scores; TD: Toy delay; SD: Standard deviation; EF: Executive function; MDS: Memory-for-designs spatial; NMRG: Narrative memory recognition; NEPSY-II: NEPSY Second Edition; IQR: Interquartile range.

(F [3, 236] = 3.22, η^2 = 0.07, P = 0.045); ADHD-C subtype displayed significantly higher total error scores than NC group (F [3, 236] = 2.74, η^2 = 0.06, P = 0.044).

The CIs and Matrices tasks shared similar findings among ADHD subtypes. The ADHD-C and ADHD-HI subtypes had significantly lower scores than NC group. However, no significant differences were found between the ADHD-I subtype and NC group. The ADHD subtypes had no significant differences from one another on these tasks. Furthermore, the ADHD-HI group had significant poorer performances compared to the ADHD-C group in the BC task (F [3, 236] = 4.89, η^2 = 0.067, P = 0.003). Likewise, no significant differences were found on Memory Delay tasks, NM tasks, AR tasks, and TM tasks.

Discussion

Previous studies have proposed that preschool children with ADHD had difficulties on neuropsychological function. However, previous research has rarely reported whether poor neuropsychological function differs among ADHD subtypes have already emerged in preschool children. The study aimed to assess neuropsychological function in Chinese preschool children with ADHD and to investigate the differences among ADHD subtypes using broad neuropsychological measures and the BRIEF-P.

Preschool children with ADHD had significant difficulties on the rating scale (BRIEF-P) of Inhibition, Shift, Emotional Control, Working Memory, and Plan/Organize, and on the tasks of Memory Delay, Statue, WG, CIs, VP, Toy Gratification Delay, and Matrices. These findings were in line with previous studies that the central domains of EF (response inhibition, working memory, and shift) were closely associated with ADHD symptoms.[20-22] Numerous previous research indicated that response inhibition and delay aversion had medium-to-large effect sizes, whereas small effect sizes were observed for working memory.[20,23-26] In addition, the findings on VP indicated that, while ADHD-HI subtype was susceptible to impulsive, ADHD-C subtype showed more difficulty to finish tasks. Concerning the significant difference in Toy Gratification Delay, our findings were supported by previous findings that children with ADHD were more sensitive to pre-reward delays than NC.[27,28]

Significant group differences were found that all ADHD subtypes differed from one another on the inhibition domain, regardless of rating scale and neuropsychological measures, suggesting that ADHD symptoms are characterized by weakness in inhibitory controls and that general poor EF may stem from poor performance on inhibition. This study found that preschool children with ADHD-I had poorer performance on rating scale involved in inhibition, working memory, and plan abilities but not on neuropsychological measures. ADHD-C preschoolers showed significantly poorest performance on all domains of rating scale, as well as on the Statue, CIs, VP, and Matrices Tasks. These findings were supported by previous studies, which showed no compelling evidence to support deficits on working memory.[27,29,30] However, some studies have found difficulties on working memory and TM in ADHD.[31] A possible explanation for this discrepancy was that working memory function was still developing in the preschool period[32,33] and was not associated with ADHD symptoms until an older age. The "hot EF", such as emotional self-regulation and TM, may also be insufficient during the preschool period. Furthermore, some studies have argued that the inappropriateness of using IQ as a covariate for working memory and other EF weakness inherent to children with ADHD may remove a portion of the variance that was shared between ADHD symptoms and EF impairment.[34,35] Children with ADHD were comparable to NC on NM tasks, which could be partly accounted for by the previous finding that IQ score influenced the association between ADHD assessment and language skills.[36]

In line with previous findings,[37] the findings suggested that preschool children with ADHD had lower IQ scores than NC group. Some studies have proposed that the correlation

Table 4: Neuropsychological profiles of ADHD subtypes and NC group on NEPSY-II

EF tests	ADHD subtypes			NC group (n = 63, d)	η^2	Bonferroni group comparison (P<0.050)
	ADHD-I (n = 25, a)	ADHD-HI (n = 44, b)	ADHD-C (n = 94, c)			
MD						
MDC	29.26 ± 8.19	29.62 ± 5.95	29.68 ± 6.65	32.64 ± 7.84	0.04	NA
MDS	15.16 ± 5.93	15.16 ± 4.86	14.68 ± 4.72	16.42 ± 4.72	0.03	NA
MDT	58.53 ± 25.35	56.96 ± 17.64	55.49 ± 19.10	61.73 ± 21.39	0.03	NA
NM						
NMFC	6.00 (6.00)	10.00 (9.75)	9.00 (10.00)	11.00 (6.00)	0.02	NA
NMRG	10.16 ± 3.10	9.91 ± 2.82	9.94 ± 2.84	10.97 ± 2.62	0.03	NA
Statue	26.00 ± 6.64	23.73 ± 8.49	22.36 ± 7.62	28.27 ± 3.18	0.12	d > b, c; a > c
AR	12.58 ± 4.27	13.47 ± 4.02	12.33 ± 4.39	14.19 ± 3.19	0.05	NA
TM	10.58 ± 4.31	10.87 ± 3.84	10.14 ± 4.79	12.00 ± 4.95	0.04	NA
WG	14.37 ± 7.37	16.38 ± 5.62	14.80 ± 6.71	19.53 ± 7.69	0.09	d > c
CI	13.84 ± 4.79	13.93 ± 4.19	14.15 ± 4.58	17.02 ± 3.39	0.10	d > b, c
BC	8.42 ± 1.98	10.09 ± 3.10	8.38 ± 2.92	10.05 ± 2.38	0.10	b > c, d
VP						
VPTT	95.00 (44.00)	93.50 (57.50)	121.00 (70.50)	121.00 (70.00)	0.07	d > b
VPTE	95.00 (70.00)	92.00 (75.00)	94.50 (66.00)	72.00 (71.00)	0.06	d < c
VPPL	1.00 (3.00)	1.00 (3.75)	1.00 (3.00)	2.00 (8.00)	0.05	NA
DG						
CDs	6.95 ± 0.23	6.87 ± 0.55	6.80 ± 0.82	6.95 ± 0.29	0.01	NA
CDt	2.68 ± 0.58	2.87 ± 0.41	2.69 ± 0.55	2.83 ± 0.42	0.03	NA
TD	2.00 (2.00)	2.00 (1.00)	2.00 (0.25)	2.00 (3.00)	0.05	d > b
Matrices	6.00 (3.00)	6.00 (3.00)	7.00 (2.00)	8.00 (4.00)	0.07	d > b, c

The data are shown as mean ± SD or median (IQR). ADHD: Attention-deficit/hyperactivity disorder; NCs: Normal controls; MD: Memory-for-designs; MDC: Memory-for-designs content; MDT: Memory-for-designs total; NM: Narrative memory; NMFC: Narrative memory free cued recall; AR: Affect recognition; TM: Theory of mind; WG: Word generation; CIs: Comprehension of instructions; BC: Block construction; VP: Visuomotor precision; VPTT: Visuomotor precision total time; VPTE: Visuomotor precision total error; VPPL: Visuomotor precision pencil lift total; DG: Delay of gratifications; CDs: Candy delay seven scores; CDt: Candy delay three scores; TD: Toy delay; NA: Not applicable since group contrast is not significant at P>0.05; SD: Standard deviation; EF: Executive function; MDS: Memory-for-designs spatial; NMRG: Narrative memory recognition; ADHD-I: ADHD-inattentive; ADHD-HI: ADHD-hyperactive/impulsive; ADHD-C: ADHD-combined; NEPSY-II: NEPSY Second Edition; IQR: Interquartile range.

between ADHD and intelligence was partially mediated by EF and non-EF.[38] In addition, a body of previous studies found that IQ was associated with EF performance.[27,39,40] Given that executive dysfunction is related to poorer IQ in children with ADHD, most previous ADHD studies have regarded IQ as a covariate to decrease the error variance. However, Barkley[3] and Warner-Rogers *et al.*[41] proposed that ADHD symptoms and EF weakness might directly cause poor performance on intelligence tests. Therefore, controlling IQ might remove a portion of the variance that was shared between ADHD symptoms and EF weakness. Conversely, studies have debated whether there is an association between EF and IQ.[29-36] This issue requires further clarification. The present study showed that group differences in the Statue, WG, CI, VP, Toy Delayed Gratification, and Matrices Tasks remained significant after controlling for IQ and age, suggesting that the significant correlation between ADHD and EF was not impacted by general intelligent and age.

The two different measures of neuropsychological difficulties used in the present study assessed different aspects of neuropsychology and shared little overlap.[9-12] The BRIEF-P is important for assessing EF weakness in children's daily lives, whereas neuropsychological measures mainly focus on laboratory conditions. In line with previous findings, the findings showed that the ADHD children were difficulties in almost all domains of the BRIEF-P and that the ADHD children had no differences among different presentations on the memory for design, NM, AR, TM, and BC tasks. The results indicated that the performance-based tests might make it difficult to systematically assess the nature of EF. Together, the two types of measures provide useful and valuable information from different perspectives.

The much lower or poorer developing in preschool children might last into school-age years or longer. Nonmedication treatment is the main intervening measure for preschoolers with ADHD. However, there is no efficient and specific intervention treatment for ADHD symptoms.[42,43] Hence, the results in this study probably provided some evidences to explore and develop potential intervention for preschoolers with ADHD, for example, to establish individual intervention treatment method and strategy based on the precise and comprehensive assessment of EF.

Some limitations of this study must be considered when interpreting our results. First of all, the ADHD-I sample was smaller than the other ADHD subtypes. It is the fact that the proportion of ADHD-I presentation in preschoolers is relatively low. Therefore, future research should involve substantial samples of preschoolers with ADHD-I. Furthermore, it was hard to clarify if the different parenting patterns resulted from disruptive behaviors in children with ADHD-C and ADHD-HI are a potential confounder in our findings. Get moreover, the study did not classify the severity of ADHD symptoms. Although in DSM-5, there is a description for specifying current severity of ADHD, no appropriate and reliable tools are available to evaluate the severity.

In conclusion, this study first demonstrated that Chinese preschool children with ADHD had difficulties in almost all domains of the BRIEF-P. Generally, preschool children with ADHD developed poorly on some aspects of EFs and related abilities on inhibition, executions, sensorimotor, verbal productivity, and nonverbal reasoning, which could be measured by the Statue, CIs, WG, VP, Toy Delayed Gratification, and Matrices Tasks. In particular, response inhibitory difficulty was found to be the central domain of EF weakness and could differentiate ADHD presentations and healthy children. In terms of EF weakness among ADHD presentations and NC, our findings suggested that all ADHD presentations had difficulties on several domains of the BRIEF-P and that the ADHD-C children had the poorest EF dysfunction assessed by the BRIEF-P. In contrast, the results showed that the children with ADHD-C and ADHD-HI were comparable on neuropsychological measures, with the exception of the BC task which assesses the visuospatial processing. Furthermore, no significant differences were found between the ADHD-I children and NCs on neuropsychological measures. These findings reinforced the notion that the BRIEF-P and neuropsychological measures provide comprehensive but different EF weakness assessments. The results from this research provided data and indications that the early intervention on those poor developing areas should be emphasized when developing nonmedication treatment for the ADHD preschoolers.

Acknowledgments

We would like to thank the parents and children for their contributions to the study.

Financial support and sponsorship

This work was supported by a grant from Science and Technological Commission of Shanghai Municipality (No. 14411968600).

Conflicts of interest

There are no conflicts of interest.

References

1. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). 5th ed. Arlington, VA: American Psychiatric Association; 2013.
2. Shuai L, Chan RC, Wang Y. Executive function profile of Chinese boys with attention-deficit hyperactivity disorder: Different subtypes and comorbidity. Arch Clin Neuropsychol 2011;26:120-32. doi: 10.1093/arclin/acq101.
3. Barkley RA. Executive functions: What they are, how they work, and why they evolved. Dev Neuropsychol 2013;38:78-80. doi: 10.1080/87565641.2012.744756.
4. Schwenck C, Schmiedeler S, Zenglein Y, Renner T, Romanos M, Jans T, *et al.* Reflective and impulsive reactions in ADHD subtypes. Atten Defic Hyperact Disord 2009;1:3-10. doi: 10.1007/s12402-009-0002-6.
5. Pennington BF, Ozonoff S. Executive functions and developmental psychopathology. J Child Psychol Psychiatry 1996;37:51-87. doi: 10.1111/j.1469-7610.1996.tb01380.x.
6. Silver CH. Sources of data about children's executive functioning: Review and commentary. Child Neuropsychol 2014;20:1-3. doi: 10.1080/09297049.2012.727793.
7. Çak HT, Çengel Kültür SE, Gökler B, Öktem F, Taşkıran C. The behavior rating inventory of executive function and continuous performance test in preschoolers with attention deficit hyperactivity disorder. Psychiatry Investig 2017;14:260-70. doi: 10.4306/pi.2017.14.3.260.
8. Korkman M, Kirk U, Kemp S. NEPSY-II: Clinical and Interpretation Manual. San Antonio, TX: Harcourt Assessment; 2007.
9. Barkley RA, Murphy KR. Impairment in occupational functioning and adult ADHD: The predictive utility of executive function (EF) ratings versus EF tests. Arch Clin Neuropsychol 2010;25:157-73. doi: 10.1093/arclin/acq014.
10. Toplak ME, West RF, Stanovich KE. Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? J Child Psychol Psychiatry 2013;54:131-43. doi: 10.1111/jcpp.12001.
11. Biederman J, Petty CR, Fried R, Black S, Faneuil A, Doyle AE, *et al.* Discordance between psychometric testing and questionnaire-based definitions of executive function deficits in individuals with ADHD. J Atten Disord 2008;12:92-102. doi: 10.1177/1087054707305111.
12. Miranda A, Colomer C, Mercader J, Fernández MI, Presentación MJ. Performance-based tests versus behavioral ratings in the assessment of executive functioning in preschoolers: Associations with ADHD symptoms and reading achievement. Front Psychol 2015;6:545. doi: 10.3389/fpsyg.2015.00545.
13. Ten Eycke KD, Dewey D. Parent-report and performance-based measures of executive function assess different constructs. Child Neuropsychol 2016;22:889-906. doi: 10.1080/09297049.2015.1065961.
14. Scheeringa MS, Haslett N. The reliability and criterion validity of the diagnostic infant and preschool assessment: A new diagnostic instrument for young children. Child Psychiatry Hum Dev 2010;41:299-312. doi: 10.1007/s10578-009-0169-2.
15. Liu J, Lynn R. Factor structure and sex differences on the Wechsler preschool and primary scale of intelligence in China, Japan and United States. Pers Individ Dif 2011;50:1222-6. doi: 10.1016/j.paid.2011.02.013.
16. Gioia GA, Espy KA, Isquith PK. Behavior Rating Inventory of Executive Function – Preschool Version. Odessa, FL: Psychological Assessment Resources; 2003.
17. Lu TF, Shuai L, Zhang JS, Wang YF, Qian Y, Zhang HF, *et al.* Validity and reliability of the behavior rating scale of executive function-preschool version parent form in China (in Chinese). Chin Ment Heal J 2017;31:138-43. doi: 10.3969/j.issn.1000-6729.2017.02.009.
18. Elliott CD. DAS-II: Administration and Scoring Manual. San Antonio, TX: Harcourt Assessment; 2007.
19. Kochanska G, Coy KC, Murray KT. The development of self-regulation in the first four years of life. Child Dev 2001;72:1091-111. doi: 10.1111/1467-8624.00336.
20. Skogan AH, Zeiner P, Egeland J, Rohrer-Baumgartner N, Urnes AG, Reichborn-Kjennerud T, *et al.* Inhibition and working memory in young preschool children with symptoms of ADHD and/or oppositional-defiant disorder. Child Neuropsychol 2014;20:607-24. doi: 10.1080/09297049.2013.838213.
21. Mahone EM, Hoffman J. Behavior ratings of executive function among preschoolers with ADHD. Clin Neuropsychol 2007;21:569-86. doi: 10.1080/13854040600762724.
22. Skogan AH, Zeiner P, Egeland J, Urnes AG, Reichborn-Kjennerud T, Aase H, *et al.* Parent ratings of executive function in young preschool children with symptoms of attention-deficit/-hyperactivity disorder. Behav Brain Funct 2015;11:16. doi: 10.1186/s12993-015-0060-1.
23. Pauli-Pott U, Becker K. Neuropsychological basic deficits in preschoolers at risk for ADHD: A meta-analysis. Clin Psychol Rev 2011;31:626-37. doi: 10.1016/j.cpr.2011.02.005.
24. Coghill DR, Seth S, Matthews K. A comprehensive assessment of memory, delay aversion, timing, inhibition, decision making and variability in attention deficit hyperactivity disorder: Advancing

beyond the three-pathway models. Psychol Med 2014;44:1989-2001. doi: 10.1017/S0033291713002547.

25. Pauli-Pott U, Dalir S, Mingebach T, Roller A, Becker K. Attention deficit/hyperactivity and comorbid symptoms in preschoolers: Differences between subgroups in neuropsychological basic deficits. Child Neuropsychol 2014;20:230-44. doi: 10.1080/09297049.2013.778236.
26. Kuntsi J, Oosterlaan J, Stevenson J. Psychological mechanisms in hyperactivity: I. Response inhibition deficit, working memory impairment, delay aversion, or something else? J Child Psychol Psychiatry 2001;42:199-210. doi: 10.1111/1469-7610.00711.
27. Sonuga-Barke EJ, Dalen L, Remington B. Do executive deficits and delay aversion make independent contributions to preschool attention-deficit/hyperactivity disorder symptoms? J Am Acad Child Adolesc Psychiatry 2003;42:1335-42. doi: 10.1097/01.chi.0000087564.34977.21.
28. Tripp G, Alsop B. Sensitivity to reward delay in children with attention deficit hyperactivity disorder (ADHD). J Child Psychol Psychiatry 2001;42:691-8. doi: 10.1111/1469-7610.00764.
29. Gathercole SE, Alloway TP. Practitioner review: Short-term and working memory impairments in neurodevelopmental disorders: Diagnosis and remedial support. J Child Psychol Psychiatry 2006;47:4-15. doi: 10.1111/j.1469-7610.2005.01446.x.
30. Qian Y, Chen M, Shuai L, Cao QJ, Yang L, Wang YF, *et al.* Effect of an ecological executive skill training program for school-aged children with attention deficit hyperactivity disorder: A Randomized controlled clinical trial. Chin Med J 2017;130:1513-20. doi: 10.4103/0366-6999.208236.
31. Re A, De Franchis V, Cornoldi C. Working memory control deficit in kindergarten ADHD children. Child Neuropsychol 2010;16:134-44. doi: 10.1080/09297040903373404.
32. Shuai L, Daley D, Wang YF, Zhang JS, Kong YT, Tan X, *et al.* Executive function training for children with attention deficit hyperactivity disorder. Chin Med J 2017;130:549-58. doi: 10.4103/0366-6999.200541.
33. Gathercole SE, Pickering SJ, Ambridge B, Wearing H. The structure of working memory from 4 to 15 years of age. Dev Psychol 2004;40:177-90. doi: 10.1037/0012-1649.40.2.177.
34. Dennis M, Francis DJ, Cirino PT, Schachar R, Barnes MA, Fletcher JM, *et al.* Why IQ is not a covariate in cognitive studies of neurodevelopmental disorders. J Int Neuropsychol Soc 2009;15:331-43. doi: 10.1017/S1355617709090481.
35. Miller GA, Chapman JP. Misunderstanding analysis of covariance. J Abnorm Psychol 2001;110:40-8. doi: 10.1037/0021-843X.110.1.40.
36. Rohrer-Baumgartner N, Zeiner P, Egeland J, Gustavson K, Skogan AH, Reichborn-Kjennerud T, *et al.* Does IQ influence associations between ADHD symptoms and other cognitive functions in young preschoolers? Behav Brain Funct 2014;10:16. doi: 10.1186/1744-9081-10-16.
37. Frazier TW, Demaree HA, Youngstrom EA. Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder. Neuropsychology 2004;18:543-55. doi: 10.1037/0894-4105.18.3.543.
38. Tillman CM, Bohlin G, Sørensen L, Lundervold AJ. Intellectual deficits in children with ADHD beyond central executive and non-executive functions. Arch Clin Neuropsychol 2009;24:769-82. doi: 10.1093/arclin/acp075.
39. Arffa S. The relationship of intelligence to executive function and non-executive function measures in a sample of average, above average, and gifted youth. Arch Clin Neuropsychol 2007;22:969-78. doi: 10.1016/j.acn.2007.08.001.
40. Harrier LK, DeOrnellas K. Performance of children diagnosed with ADHD on selected planning and reconstitution tests. Appl Neuropsychol 2005;12:106-19. doi: 10.1207/s15324826an1202_6.
41. Warner-Rogers J, Taylor A, Taylor E, Sandberg S. Inattentive behavior in childhood: Epidemiology and implications for development. J Learn Disabil 2000;33:520-36. doi: 10.1177/002221940003300602.
42. Strawn JR, Dobson ET, Giles LL. Primary pediatric care psychopharmacology: Focus on medications for ADHD, depression, and anxiety. Curr Probl Pediatr Adolesc Health Care 2017;47:3-14. doi: 10.1016/j.cppeds.2016.11.008.
43. Huang F, Sun L, Qian Y, Liu L, Ma QG, Yang L, *et al.* Cognitive function of children and adolescents with attention deficit hyperactivity disorder and learning difficulties: A Developmental perspective. Chin Med J 2016;129:1922-8. doi: 10.4103/0366-6999.187861.

学前注意缺陷多动障碍儿童神经心理功能评估：神经心理学工具和学龄前儿童执行功能行为评定问卷

摘要

背景：既往研究发现学龄前注意缺陷多动障碍（ADHD）儿童的神经心理功能存在损害。本研究采用神经心理学工具和相关的评定量表，用以评定我国学前ADHD儿童的神经心理功能状况，以及不同ADHD亚型神经心理学弱点的模式和严重程度是否存在差异。

方法：226名年龄为4–5岁的学前儿童包括ADHD患儿163名及正常儿童63名被纳入本研究。所有儿童接受学前儿童执行功能行为评定量表（BRIEF-P）父母版问卷调查和一系列神经心理学测试以评估神经心理学功能。

结果：学前ADHD儿童的BRIEF-P问卷各因子得分均较正常儿童高，且具有统计学意义 (抑制因子: 30.64 ± 5.78 vs.20.69 ± 3.86, P <0.001; 转换因子: 13.40 ± 3.03 vs.12.41 ± 2.79, P =0.039; 情绪控制因子:15.10 ± 3.53 vs.12.20 ± 2.46, P <0.001; 工作记忆因子: 28.41 ± 4.99 vs.20.95 ± 4.60, P <0.001;组织 / 计划因子: 17.04 ± 3.30 vs.13.29 ± 2.40, P <0.001)。在雕塑测试(23.18 ± 7.84 vs.28.27 ± 3.18, P =0.001)、词汇生成(15.22 ± 6.52 vs.19.53 ± 7.69, P =0.025)、指令理解(14.00 ± 4.44 vs.17.02 ± 3.39, P =0.016)、视觉运动(P <0.050)、玩具延迟满足(P =0.048)和矩阵推理神经心理学任务(P=0.011)中，学前ADHD儿童表现较正常儿童差，且具有统计学意义。学前ADHD各亚型儿童在BRIEF-P问卷的抑制因子、工作记忆因子、组织计划因子得分均较正常儿童高 (P<0.001)，且ADHD混合型儿童在抑制因子和组织计划因子上得分最低。在雕塑测试中，ADHD混合型儿童表现较ADHD注意缺陷型儿童差(F=7.34, η^2=0.12, P<0.001)。在积木任务中，ADHD冲动型儿童表现较ADHD混合型儿童差(F=4.89, η^2=0.067, P=0.003)。在神经心理学任务中，尚未发现ADHD注意缺陷型儿童的表现与正常儿童表现有显著差异。

结论：通过BRIEF-P问卷评估和神经心理学任务评估，本研究发现学前ADHD儿童存在着多方面的神经心理功能损害。