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Attention Deficit/Hyperactivity Disorder (ADHD): Age Related Change of Completion Time and Error Rates of Stroop Test

CEMPAKA THURSINA[1,2], MAWADDAH AR ROCHMAH[4], DIAN KESUMAPRAMUDYA NURPUTRA[3,4], INDRA SARI KUSUMA HARAHAP[2], NUR IMMA FATIMAH HARAHAP[4], NIHAYATUS SA'ADAH[5], SAMEKTO WIBOWO[2], SRI SUTARNI[2], AHMAD HAMIM SADEWA[5], NORIYUKI NISHIMURA[4,6], TSURUE MANDAI[6], KAZUMOTO IIJIMA[6], HISAHIDE NISHIO[4,6*], SHINJI KITAYAMA[6]

[1]*Doctoral Programme of Medical and Health Science, Faculty of Medicine Universitas Gadjah Mada, Yogyakarta, Indonesia.*

[2]*Department of Neurology, Faculty of Medicine Universitas Gadjah Mada, Yogyakarta, Indonesia.*

[3]*Department of Pediatrics, Faculty of Medicine Universitas Gadjah Mada, Yogyakarta, Indonesia.*

[4]*Department of Community Medicine and Social Health Care Science, Kobe University Graduate School of Medicine, Kobe, Japan*

[5]*Department of Biochemistry, Faculty of Medicine Universitas Gadjah Mada, Yogyakarta, Indonesia.*

[6]*Department of Pediatrics, Kobe University Graduate School of Medicine, Kobe, Japan*

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BACKGROUND: Attention Deficit/Hyperactivity Disorder (ADHD) is a common neurobehavioral problem in children throughout the world. The Stroop test has been widely used for the evaluation of ADHD symptoms. However, the age-related change of the Stroop test results has not been fully clarified until now. METHODS: Sixty-five ADHD and 70 age-matched control children aged 6–13 years were enrolled in this study. ADHD was diagnosed based on DSM-IV criteria. We examined the completion time and error rates of the Congruent Stroop test (CST) and Incongruent Stroop test (IST) in ADHD and control children. RESULTS: No significant difference was observed in the completion time for CST or IST between the ADHD and control children at 6–9 years old. However, ADHD children at 10–13 years old showed significantly delayed completion time for the CST and IST compared with controls of the same age. As for the error rates of the CST and IST, ADHD and control children at 6–9 years old showed no difference. However, error rates of CST and IST in the ADHD children at 10–13 years were significantly higher than those of control of the same age. CONCLUSIONS: Age may influence the results of Stroop test in ADHD children. For the ages of 10–13 years old, the Stroop test clearly separates ADHD children from control children, suggesting that it may be a useful screening tool for ADHD among preadolescent children.

INTRODUCTION

Attention Deficit/Hyperactivity Disorder (ADHD) is a common neurobehavioral problem in children comprising inappropriate inattention, hyperactivity and impulsivity [1,4]. ADHD is diagnosed using the standard criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV and ICD-10 [2]. The worldwide-pooled prevalence of ADHD has been reported to be 5–10% of whole children population [29,13].

It has been reported that executive function deficits are found in 30% of children with ADHD [9]. We often observe that learning disabilities in school-age children with ADHD arise from deficits in the executive functions of the brain [9,26]. Executive functions comprise several mental processes which are necessary to regulate daily life tasks, including organizational skill, power of concentration, inhibitory control, processing speed, emotional regulation, and working and short-term memory which are summarized as cognitive skills [15].

Many tools have been developed in evaluating the cognitive function of children with ADHD. The Intelligence Quotient Test (IQ Test), Modified Mini Mental State and Examination for Children (MMMSEC), and Stroop test are some of the accepted tools [8,34]. The Stroop test, also referred to as the Stroop Color Word test, has been seen as the most feasible and reliable test which evaluates the cognitive function of inhibitory control in the clinical setting [41]. Several studies have reported that the Congruent Stroop Test (CST) and Incongruent Stroop Test (IST) are able to show the difference in the development of cognitive function between children with ADHD and normally developed children in various populations in the world [18,21].

Phone: +81-78-382-5540 Fax: +78-382-5559 E-mail: nishio@med.kobe-u.ac.jp

ADHD children have shown age-related improvement of symptoms [5]. However, in some ADHD children, the symptoms may persist into adolescence and adulthood. To investigate the age-related change of cognitive or executive function development in ADHD, we analyzed the results of IQ test, MMSEC and Stroop test of ADHD and control children. Especially, the age-related change of the Stroop test results has not been fully clarified until now. Here, we assigned ADHD and control children into four age groups (6–7, 8–9, 10–11, and 12–13 years old), and then compared their profiles of Stroop test results.

SUBJECTS AND METHODS

Subjects

Care givers (teachers and parents) used Abbreviated Corner's Teachers Rating Scale (ACTRS) and Abbreviated Corner's Parent Rating Scale (ACPRS) forms to screen for ADHD in 1,480 students of 10 different elementary schools in Cangkringan, Yogyakarta, Indonesia. Suspected children with ADHD were examined by the designated psychologist and neurologist. The diagnosis was made based on the criteria of "Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV". Sixty-five students who were diagnosed as children with ADHD (58 boys and 7 girls, 9.49 ±1.78 years old (Mean±SD)) and 70 control children (62 boys and 8 girls, 9.50 ±1.68 years old) were enrolled in this study. ADHD and control children were matched for age and gender. They had no problems with their hearing, vision (including color blindness) or other neurological disorders. None of the children with ADHD had received pharmacological treatment during the study. This study was approved by the Ethics Committee of Faculty of Medicine Universitas Gadjah Mada, Yogyakarta, Indonesia. Informed consent was obtained from the student's care-givers.

IQ test

"Wechsler Intelligence Scale (WISC) III" was used to measure IQ. This IQ test is divided into two scales: a verbal scale consisting of six subtests, and a performance scale consisting of seven subtests. Each scale has five designated standard subtests that are used to compute Verbal IQ (VIQ), Performance IQ (PIQ) and Full Scale IQ (FSIQ), as mentioned in a previous report [11].

MMMSEC test

A modified version of the Mini Mental State Examination (MMSE) for children was used in this study. The test includes 5 sub-tests for assessment of cognitive functions comprising orientation, attention, registration, recall memory, and language. We used the scores to categorize the level of the cognitive ability. The maximum score of the MMMSEC is 37 points [16].

Stroop test

In this study, the Stroop test card was modified to the local culture and language. In our modified version, Stroop test cards consisted of two cards, with each card having four columns and six rows. The Stroop cards contained colored-words for pronouncing the name of the color in the Indonesian language. The first card used ink colors congruent with the names of the colors, and the second card used incongruent ink colors to write the names of the colors. For the CST, we used the first card and the children were asked to name the colors (for example, the word "yellow" was printed in "yellow" colored ink), while for the IST, we used the second card and asked the children to name the color of the word regardless of the word itself (for example, if the word "yellow" was printed in a "blue" color, to say "blue").

Statistical analysis

Baseline characteristics and demographic data were analyzed by using chi-square and unpaired t-test. Age-related mean score differences of Stroop test, IQ and MMSEC between ADHD and control groups were analyzed by using one way analysis of variance (ANOVA) in multiple group comparisons method. Significances of individual differences were evaluated by the Tukey HSD post hoc test if ANOVA was significant. A probability of less than 0.05 was considered statistically significant.

Table I. Characteristics of the participants in this study

	ADHD	CONTROL	P
Participants (M/F)	65 (58/7)	70 (62/8)	0.99†
Mean Age (SD)	9.49 (1.78)	9.50 (1.68)	0.98†
Age distribution			
6-7 y	9/1	5/1	0.67††
8-9 y	24/3	34/2	
10-11 y	14/2	15/1	
12-13 y	11/1	8/4	
Parents' information			
Fathers' education			
Elementary School	22	18	0.71††
Junior High School	22	19	
Senior High School	20	29	
College	1	4	
Occupations			
Farmer	33	36	0.71††
Private sector	24	21	
Government employee	6	9	
Army/Police	2	4	
Mean monthly income			
(SD) (in Rp 1,000)	1,169 (574)	1,335 (681)	0.17††
Cognitive profiles			
IQ test			
VIQ	103.34 (15.18)	113.45 (12.17)	<0.01†††
PIQ	97.48(13.00)	100.34 (9.28)	0.18†††
FSIQ	101.70 (13.31)	107.70 (10.67)	<0.01†††
MMMSEC			
Orientation	9.99 (1.66)	11.10 1.08)	<0.01†††
Registration	2.69 (0.49)	2.91 (0.30)	<0.01†††
Calculation	6.76 (0.55)	6.78 (0.61)	0.87†††
Recall/Memory	2.63 (0.65)	2.91 (0.37)	<0.01†††
Language	10.90 (1.39)	11.68 (0.71)	<0.01†††
Total score	32.98 (2.41)	35.38 (1.87)	<0.01†††
Stroop test			
Congruent Stroop test			
Completion time	25.28 (3.79)	18.41 (3.25)	<0.01†††
Error rate	1.79 (1.23)	1.23 (0.42)	<0.01†††
Incongruent Stroop Test			
Completion time	34.90 (8.13)	28.87 (4.17)	<0.01†††
Error rate	2.32 (1.86)	1.86 (0.75)	0.02†††

ADHD: Attention Deficit Hyperactivity Disorder, SD: Standard Deviations, IQ: Intelligence Quotient, VIQ: Verbal IQ, PIQ: Performance IQ, FIQ: Full Scale IQ, MMMSEC: Modified Mini Mental State Examination for Children. †, ††, †††: t-test, chi-square test, ANOVA, respectively.

RESULTS

Background of ADHD children in this study

The baseline characteristics of the children who participated in this study are given in Table I. There were no differences in age (p=0.98) and gender (p=0.99) between ADHD and control children. The boy to girl ratio of ADHD is 9 to 1. Distribution of jobs, monthly income, and educational level of parents were equal between ADHD and control children group (Table I).

We assigned the children into 4 groups: ages 6–7, 8–9, 10–11, and 12–13 years old. The percentage of ADHD case numbers in each age group of boys was 3% at 6–7 years old, 7% at 8–9 years old, 4% at 10–11 years old, and 3% at 12–13 years old, while those of girls were 0.3% at 6–7 years old, 0.8% at 8–9 years old, 0.5% at 10–11 years old, and 0.3% at 12–13 years old. The case number was the highest at ages 8–9 years old. The case numbers increased from 6–7 years old until 8–9 years old and gradually decreased in the older age groups (Table I).

Intelligence Quotient (IQ) test

We used the WISC III in this study, and compared the IQ scores between ADHD and control children (Table I). There were significant differences between ADHD and normal children in VIQ scores ($p<0.05$) and FSIQ scores ($p<0.05$): the VIQ and FSIQ scores of ADHD children were relatively lower compared with those of control children. However, there was no significant difference in PIQ (p=0.18). Interestingly, there were no significant changes in VIQ, PIQ, or FSIQ scores along with ages in ADHD and control children (Fig. 1)

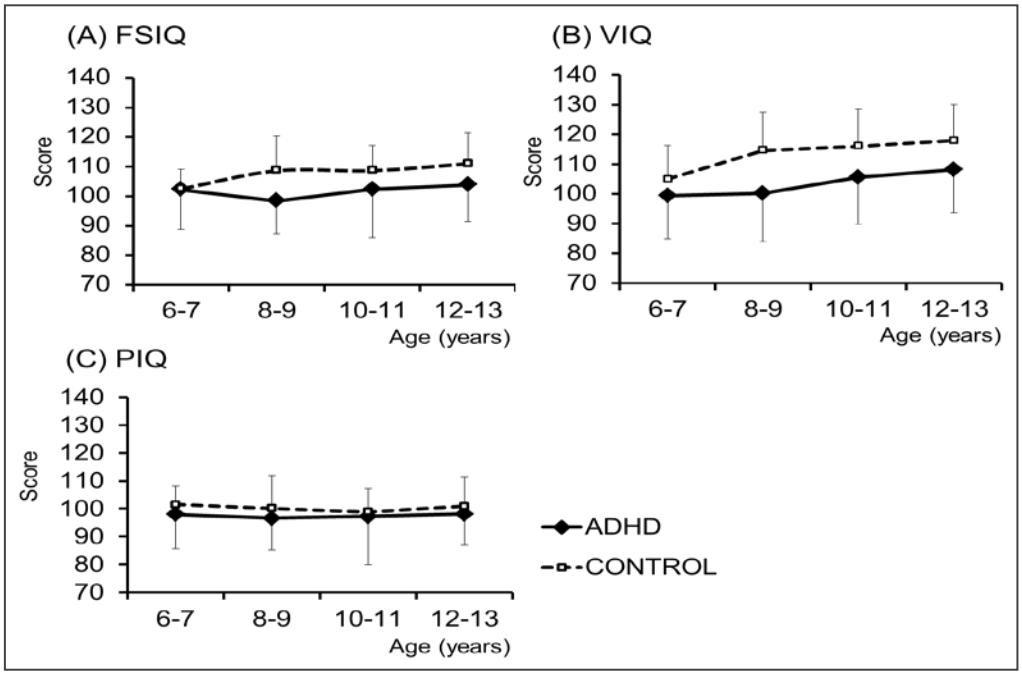

Fig 1. IQ profiles of ADHD and control children

(A) The values of the FSIQ scores of the IQ test between ADHD and control children. The values represent the mean scores in each age group. Error bars represent standard deviations.

(B) The values of the VIQ scores of the IQ test between ADHD and control children. The values represent the mean scores in each age group. Error bars represent standard deviations.

(C) The values of the PIQ scores of the IQ test between ADHD and control children. The values represent the mean scores in each age group. Error bars represent standard deviations.

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MMMSEC

We compared the MMMSEC tests in Table I and Fig. 2. There were significant differences between ADHD and normal children in orientation ($p<0.05$), language ($p<0.05$), recall/memory ($p<0.01$), registration ($p<0.01$), and total MMMSEC ($p<0.01$), but no significant difference was found in calculation (p=0.87).

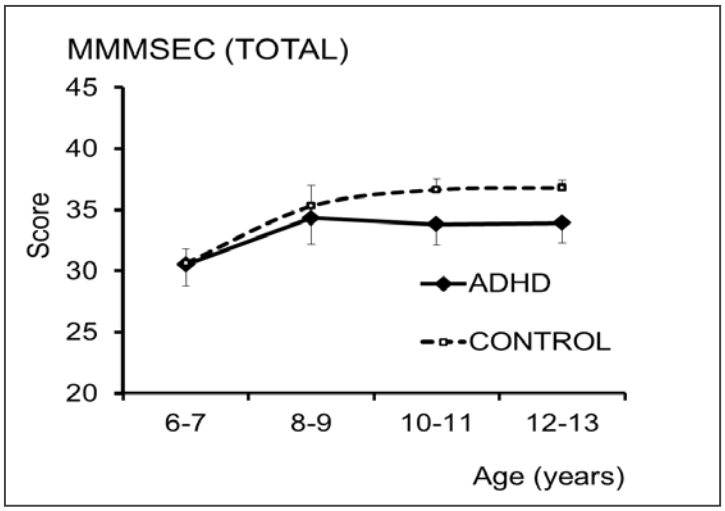

Fig 2. MMSEC (Total) Score of ADHD and control children
The values of the MMSEC scores between ADHD and control children. The values represent the mean scores in each age group. Error bars represent standard deviations.

Stroop Test

We compared the mean completion time and error rates (or error numbers per test) between children with ADHD and control children. The completion time of ADHD and control children for the Stroop tests, CST and IST, showed no significant differences before the age of 9 years (Fig. 3). However, the mean completion time of ADHD children for the CST and IST were markedly increased (or delayed) after nine years old. The control children's mean completion time for both tests decreased as they grew older. As noted above, there was a great difference in the mean completion time between ADHD and control children at 12–13 years old: 31.84±5.41 seconds (Mean±SD) for ADHD children vs. 15.38±3.88 seconds for control children ($p<0.05$) in the CST, and 46.92±13.40 seconds for ADHD children vs. 24.92±4.59 seconds for control children ($p<0.05$) in the IST.

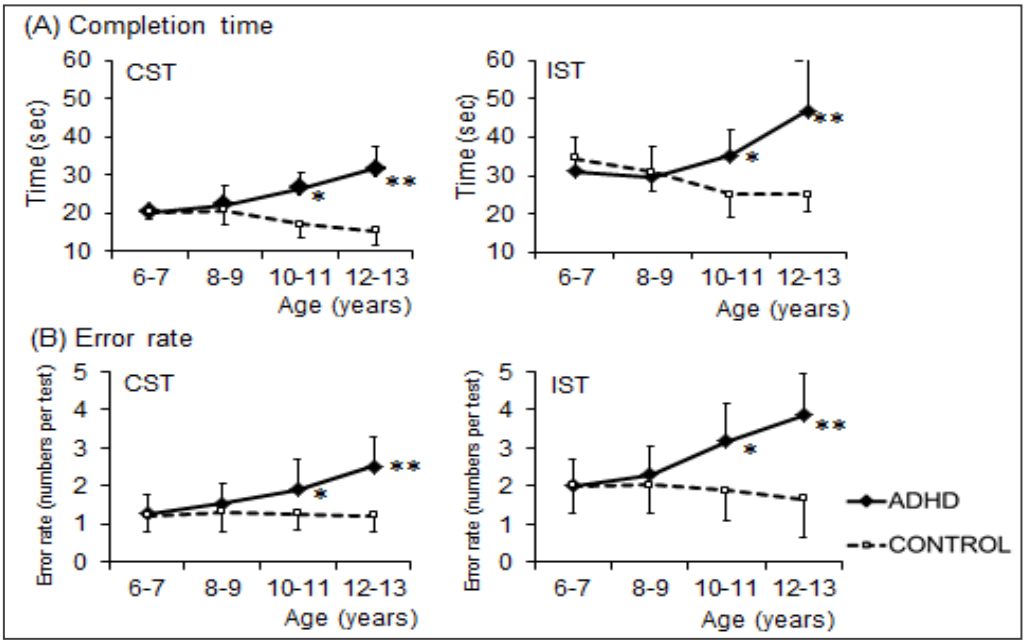

Fig 3. Stroop test results of ADHD and control children

(A) Completion Time. The completion time of the CST and IST between ADHD and control children. The values represent the mean scores in each age group. Error bars represent standard deviations. *p* value represents significance in difference, where CST:*p<0.05; **p<0.05 and IST: *p=0.008; **p<0.05

(B) Error rates. The error rates of the CST and IST between ADHD and control children. The values represent the mean scores in each age group. Error bars represent standard deviations. *p* value represents significance in difference, where CST: *p=0.01; **p<0.05 and IST: *p=0.03; **p=0.01.

We also observed that the error rates of the ADHD and control children in color-naming on the CST and IST showed no significant difference at 6–9 years old (Fig. 3). However, the error rates of the ADHD children did not decrease as they grew older, while those of the control children decreased along with age (Fig. 3).

Consequently, there was a great difference between the ADHD and control children at 12–13 year of age: 2.50±0.83 for ADHD children vs. 1.20±0.45 for control children in the CST, and 3.14±0.81 for ADHD children vs. 1.88±0.78 for control children in the IST.

DISCUSSION

We roughly estimated that the ADHD prevalence among the school age children in Yogyakarta, Indonesia, is ~4% (65 participants were diagnosed as having ADHD from 1,480 screening subjects enrolled in this study). According to our data, the case number was the highest in children at 8–9 years old, which was consistent with previous reports [13,37]. The distribution of case numbers in different age groups suggested a natural course for many ADHD children: the symptoms of ADHD; start at 6–7 years old, become prominent at 8–9 years old, and gradually improved after 10 years old. However, in some individuals, ADHD symptoms may persist into the adolescence period [3].

The IQ test has already been widely used to evaluate the cognitive function of children. In this study, it should be noted that even though the IQ mean scores of ADHD children were relatively lower than those of control children at any age, the VIQ and FSIQ scores of ADHD and control children did not drastically change with increasing age (Fig.1). This is the main difference of the IQ test from the Stroop test findings in our study.

The completion time of Stroop test in our study showed no difference between the ADHD and control children at 6 to 9 years old, but a great difference at 12–13 years old. The ADHD children's mean completion time for both tests increased as they grew older, while the control children's mean completion time for both tests decreased. We also observed no significant differences in the color-naming error rates of the CST and IST between the ADHD and control children at 6–9 years old. However, there were great differences between the ADHD and control children at 12–13 years old. ADHD children showed higher error rates compared to control children at the same age groups of 10 years old above. Our results of preadolescent children are fully consistent with those of Malek *et al*. [25]. They reported that both completion time and error rates in the Stroop test may have good differential validity to discriminate ADHD from healthy individuals from the ages of 12 to 17 years.

To support the mental development of ADHD children, it is necessary to identify the anti-"age-related-improvement" factors (or aggravating factors) which can be measured by the Stroop test, but not the IQ test. Here we propose two plausible factors. One is an innate factor associated with poor inhibitory control in the executive function; delayed brain maturation. Inhibitory control is defined as the ability to hold or suppress inappropriate interruption or information during performance of an ongoing task [23,36]. ADHD children cannot obtain inhibitory control due to the lack or delay of brain maturation [27]. The other is an acquired factor associated with inefficient learning; poor automaticity in reading. Automaticity in reading is defined as reading process characterized by speed, effortlessness, autonomy, and lack of conscious awareness, resulting in rapid and accurate reading performance [12,19]. It has been suggested that ADHD children suffer poor automaticity due to their inefficiency and disability in learning [33]. Deficits in inhibitory control and poor automaticity in reading have been reported to contribute to the longer completion time in the Stroop test and to the higher error rate [24,30,33]. Naturally enough, the two factors are not mutually exclusive. The delay of brain maturation may link to the difficulty in learning and cause poor reading ability [38,42].

ADHD children may continue to have a full or partial persistence of ADHD into adulthood [5,6]. Here, Stroop test may help clinician to detect persistent ADHD from healthy pre-adolescent in the earliest way so that treatment could be performed. Early treatment or intervention is essential to prevent adult ADHD. For the pharmacological treatment, methylphenidate has been widely used [20,31]. However, early intervention with this drug remains controversial due to the risk of later substance abuse [14,17]. Thus, non-pharmacological treatments are now considered as the first-line interventions, since they are usually safer compared with drugs. Only when necessary, the pharmacological approach can be combined with non-pharmacological treatments. There are many kinds of non-pharmacological treatments, e.g., restricted elimination diet [10,28], free fatty acid supplementation, neuro-feedback therapy [7,22,40], class room intervention, social skill training [39,43], and parenting behavioral intervention [32,35]. Parents, care givers and doctors must seek the best approaches for each child with ADHD.

In conclusion, we showed the age-related change of ADHD symptoms on the basis of cross-sectional (or non-longitudinal) observation. For the children at 6–9 years old, there was no difference in the Stroop test between ADHD and control children, while for the children above 9 years old, there was a significant difference in the Stroop test between ADHD and control children. For the ages 10-13 years old, the Stroop test clearly separated ADHD children from control children, suggesting that it may be a useful screening tool for ADHD among preadolescent children.

AUTHORS' CONTRIBUTION

CEMPAKA THURSINA, MAWADDAH AR ROCHMAH, and DIAN KESUMAPRAMUDYA NURPUTRA contributed equally to this work.

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