Gender differences in executive functions and reading abilities in children with attention deficit hyperactivity disorder

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Background

Executive function (EF) develops throughout childhood and adolescence. Up to half of youth with attention deficit hyperactivity disorder (ADHD) show executive dysfunction. Reading disability has a comorbidity with ADHD of 20–40%. Adequate reading comprehension depends on higher cognitive skills beyond word decoding.

Aim

The aim of this study was to investigate EFs and reading abilities in a group of primary school children with ADHD [intelligence quotient (IQ) $\geq$ 85] and whether they differ with sex.

Methods

A total of 30 Egyptian boys and 30 girls aged 8–12 years diagnosed with ADHD were compared with 40 healthy matched controls in terms of clinical assessment of reading skills, comorbidites, IQ, ADHD symptoms using Conners' Parent Rating Scale-Revised-Long version (CPRS-R-L), EFs using the Wisconsin Card Sorting Test (WCST), and metacognitive reading using the Metacognitive Reading Comprehension Scale.

Results

In total, 50% of ADHD cases showed the combined type, 31.7% the predominantly inattentive, and 18.3% the predominantly hyperactive type, with a significant gender difference (P=0.007). Patients had significantly higher scores in all CPRS-R-L scales, except for the anxious–shy subscale. Boys had higher means in the 'hyperactivity', whereas girls had higher means in the 'cognitive problems/inattention' scale.

Male and female patients did not differ in comorbid learning disabilities but differed in conduct disorder and depression. Patients scored significantly lower on all WCST indices, except the first trials (P < 0.001). Girls with ADHD made more errors, P=0.050, and completed less number of categories than boys, P=0.024. EF did not correlate with the hyperactivity subscale of CPRS-R-L. It correlated with the cognitive problems/inattention subscale in male and female patients. The Metacognitive Reading Comprehension scores differed significantly between the children with ADHD and the controls (P < 0.001). None of the WCST indices predicted the Metacognitive Reading Comprehension total score. The total score was predicted only by the CPRS-R-L N scale (DSM-IV total), but not by its other subscales, IQ scales, sex, or age.

Conclusion

Children with ADHD have lower EF and reading abilities than controls. Executive dysfunction is related to inattention and not to hyperactivity. No robust differences in EF can be attributed solely to sex. Reading and metacognitive reading dysfunctions showed no gender difference.

Keywords:

attention deficit hyperactivity disorder, executive functions, metacognitive reading, gender difference

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Introduction

The term executive functions (EFs) refers to a set of cognitive functions that enable one to demonstrate goal-directed behavior, usually in novel contexts with competing response alternatives (Pennington and Ozonoff, 1996). Cognitive processes associated with EF are numerous, but the principal elements include anticipation, goal selection, planning and organization, initiation of activity, self-regulation, mental flexibility, deployment of attention, working memory, and utilization of feedback (Anderson, 2002). These abilities are considered 'executive' because they are believed to subserve a supervisory role that involves integrating information stored elsewhere in the brain (Shallice, 2004) and can have the potential to affect the processing of other domains of cognition: learning, memory, language, and visual perception (Scalan, 2003).

EF develops throughout childhood and adolescence and plays an important role in a child's cognitive functioning, behavior, emotional control, and social interaction. Attentional control appears to emerge in infancy and to develop rapidly in early childhood. In contrast, cognitive flexibility, goal setting, and information processing experience a critical period of development, between 7 and 9 years, and are relatively mature by 12 years (Anderson, 2002).

One of the most prominent neuropsychological theories of attention deficit hyperactivity disorder (ADHD) suggests that its symptoms arise from a primary deficit in EF. However, moderate effect size and the lack of universal EF deficits among ADHD individuals suggest that EF weaknesses are 'neither necessary nor sufficient to cause ADHD' (Willcutt *et al.*, 2005), and furthermore, EF deficits are typical of developmental disorders in general, such as autism (Pennington and Ozonoff, 1996).

The literature reveals that approximately half of youth with ADHD show executive dysfunction (Nigg *et al.*, 2005). The fact that not every person with ADHD is impaired on every test and some individuals with ADHD perform within the normal range on all or most measures demonstrates heterogeneity in ADHD (Hong *et al.*, 2010). Wåhlstedt *et al.* (2009) pointed to the importance of viewing ADHD as a heterogeneous condition with respect to the differential impacts of both neuropsychological functioning and comorbidities on different ADHD symptom groups and the two ADHD symptom domains.

ADHD and reading disability are two common childhood disorders that frequently co-occur. Research estimates the comorbidity of reading disability in children with ADHD to be between 20 and 40% (Del'Homme *et al.*, 2007). Adequate reading comprehension depends on cognitive skills beyond word decoding, including reading fluency, language comprehension, and other higher EF skills, for example, working memory, planning, organizing and monitoring, reasoning, and critical analysis (Vellutino *et al.*, 2000). Individuals with good reading comprehension are more likely to use cognitive and metacognitive strategies (Pearson and Fielding, 1991). In contrast, children who struggle with reading comprehension tend to perform worse than typically developing peers on measures that require planning an organized response (Reiter *et al.*, 2005).

Because EF deficits are particularly likely to predict continuing academic failure in youth with ADHD (Biederman *et al.*, 2004), we aimed to investigate EFs and reading abilities in a group of primary school children with an average intelligence quotient (IQ $\geq$ 85) diagnosed with ADHD and to examine whether these functions differ according to sex.

Methods

Participants

This study included a convenient sample of 60 Egyptian children (30 boys and 30 girls) diagnosed with ADHD, selected from Kasr El-Einy Pediatric Hospital (Abu-El Rish) Outpatient Psychiatry Clinic or from the Psychiatry Outpatient Clinic of Ahmed Maher Hospital on a consecutive referral basis. All children were required to be primary school children, of age range 8–12 years, having an intermediate socioeconomic standard according to the Fahmy and El-Sherbini (1983) model for social classifications. Patients were diagnosed with ADHD using the *Diagnostic and Statistical Manual of Mental Disorders, 4th ed.* (DSM-IV)-TR diagnostic criteria for ADHD (American Psychiatric Association, 2000).

Children with an IQ below 85, organic etiology, any chronic medical illness, or any visual or auditory deficit were excluded.

The control group

Forty healthy control subjects (20 males and 20 females), siblings of patients coming to the Kasr El-Einy General Pediatric Hospital (Abu-El Rish) Outpatient Clinic volunteered to undergo the procedures. They were selected to match the patients group for age, sex, IQ, educational and socioeconomic level. All of the control subjects had no previous psychiatric or neurological disease or previous psychiatric consultation.

Ethical considerations

Assent from the child and written consent from the caregiver with regard to the aim, the tools used in the research, benefits, risks, confidentiality, and voluntary participation were prerequisites.

Tools

A full psychiatric sheet was used and a clinical assessment of reading abilities using a structured sheet for the assessment of learning disabilities was carried out. The sheet assessed reading abilities, alphabet, word recognition, reading fluency, and spelling mistakes, in addition to writing abilities, in accordance with the requirements of the National Educational Grade the child is enrolled in and given that the child is of average intelligence and had an acceptable level of schooling.

Stanford–Binet Intelligence Scale (Ahmed and Meleka, 1972; the Arabic version)

It assesses the following abilities or cognitive areas: memory, comprehension, perception, language abilities, and performance abilities. IQ scores of 90–109 are considered average.

The Arabic version of Conners' Parent Rating Scale-Revised-Long version (El-Sheikh et al., 2002)

It was developed by C. Keith Conners in 1997, translated by El-Sheikh *et al.*, (2002), and validated through use in many subsequent researches. It is a paper-and-pencil screening questionnaire designed to be completed by parents. It includes 80 questions, each followed by four choices: 0 (not at all), 1 (just a little), 2 (pretty much), or 3 (very much). The following subscales are provided after scoring the test: (A) oppositional, (B) cognitive problems/inattention, (C) hyperactivity, (D) anxious–shy, (E) perfectionism, (F) social problems, (G) psychosomatic, (H) Conners' ADHD index, (I) Conners' Global Index restless/impulsive, (J) Conners' Global Index emotional lability, (K) Conners' Global Index total, (L) DSM-IV inattentive, (M) DSM-IV hyperactive–impulsive, (N) DSM-IV total. A T-score of more than 65 on the Conners' Parent Rating Scale indicates that the patient has a significant pathology.

Wisconsin Card Sorting Test (Heaton, 1981):
This test was originally developed to assess abstract reasoning ability and the ability to shift cognitive strategies in response to changing environment contingencies. The Wisconsin Card Sorting Test (WCST) requires strategic planning, organized searching, utilizing environmental feedback to shift cognitive sets, directing behavior towards achieving a goal, and modulating impulsive responding.

The WCST requires the examinee to discern the sort criterion of a set of cards on the basis of the 'correct' versus the 'incorrect' feedback provided by the examiner. After correctly matching a card according to a stimulus feature (color, form, or number) for 10 consecutive trials, the matching feature changes. This occurs six times or until all 128 cards are presented, whichever comes first. Successful performance on the WCST requires that an individual determine the correct response in dimension and then maintain responding to that dimension. The problem-solving component involves considering a variety of hypotheses and rejecting them if they prove incorrect on the basis of the feedback received. The WCST has been standardized and normed for use with children, adolescents, and adults, ranging from 6 to 89 years. Participants should have normal or corrected vision and hearing to comprehend the test instructions adequately and to visually discriminate the stimulus parameters of color, form, and number.

The following items are provided after scoring the WCST:

(1) *Number of trials administered*: A raw score of the total number of trials administered.
(2) *Total number of errors*: A raw score of the total number of errors made by the participant.
(3) *Perseverative errors*: When the patient persists in responding to a stimulus despite being told it is wrong.
(4) *Percent perseverative errors*: Raw score of the perseverative errors divided by the number of trials administered, multiplied by 100.
(5) *Perseverative responses*: It is the raw score of perseverative responses irrespective of whether they are correct or incorrect.
(6) *Percent perseverative responses*: Raw score of the perseverative responses divided by the number of trials administered, multiplied by 100.
(7) *Number of categories completed*: It is the number of categories (i.e. each sequence of 10 consecutive correct matches to the criterion sorting category) that the participant successfully completed during the test.
(8) *Trials to complete first category*: The total number of trials to successfully complete the first category provides an indication of 'initial conceptualization' before a shift of set is also required.
(9) *Failure to maintain a set*: It occurs when the client makes five or more consecutive correct matches but then makes an error before successfully completing the category.
(10) *Learning to learn*: This score reflects the client's 'average change in conceptual efficiency' across the consecutive categories (stages) of the WCST. A positive learning to learn score indicates 'improved efficiency across consecutive categories, presumably because of learning'. Note: It can be calculated only for clients who have completed two categories and have attempted a third.

Metacognitive Reading Comprehension Scale – Arabic form (Mostafa and Al-Sawy, 2003)
It was developed by Swanson and Trahan (1996). It includes 20 sentences describing different situations, each followed by four answers, so that the student chooses one correct answer for each. It is designed to measure the reading comprehension of children of primary school age.

Metacognition is defined as the person's awareness of his/her own cognitive operations and the input and the strategies needed for a cognitive task (Montague and Bos, 1986).

The following items are provided after scoring the Metacognitive Reading Comprehension Scale:

(1) *Self-monitoring score*: Each student has his/her own perceptions and feelings about himself as a reader, and these perceptions and feelings affect, either negatively or positively, his/her understanding of the written text (McNeil, 1987).
(2) *Planning of task parameters*: It reflects the reader's awareness of the importance of using different strategies during reading and his/her ability to 'plan' using them (Al-Sawy, 2003).
(3) *Assessment of strategies*: The ability of the student to 'evaluate' the strategies used during reading for a better understanding of the written text. This reflects learning about different strategies used for reading comprehension, trying them out, and comprehending them. For example, students with high metacognitive abilities know that prediction of the subject of the article on the basis of its title helps them summarize it and improves the level of understanding of the written text. Similarly, drawing a conclusion about what happened in the story even though it was not explicitly mentioned means that they have understood the implication of the story (Swanson and Trahan, 1996).
(4) *Total score*: This is the sum of the three preceding scores.

Statistical analysis
Data were analyzed using SPSS (version 16; SPSS Inc., Chicago, Illinois, USA). Data were presented using descriptive statistics of frequencies and percentages for qualitative variables and mean and SD for quantitative

variables. Variables were compared using the χ^2-test, Student's t-test, and the Mann–Whitney U-test. Pearson correlations were used to correlate quantitative variables. Stepwise linear regression analysis was used to predict a dependent variable using a set of predictor variables. Each variable is examined at each step of an equation for entry or removal. Statistical significance was considered at a P-value less than 0.05.

Results

Description of the sample

Age and intelligence quotient

The mean age of the patients was 9.18 ± 1.1 years and the mean age of the controls was 9.5 ± 1.2 years, with no statistical difference ($t = 1.29$, $P = 0.20$). Although an IQ below 85 was an exclusion criterion, the patients had a significantly lower total IQ (90.22 ± 5.3) than the controls (99.68 ± 7.409, $t = -7.45$, $P < 0.001$), with a significant difference in all Stanford–Binet Intelligence subscales ($P < 0.001$).

Male and female patients did not differ in age. The mean age of boys was 9.18 ± 1.09 years and that of girls was 9.19 ± 1.2 years ($t = -0.023$, $P = 0.98$). Boys and girls did not differ in total IQ. Boys had a total IQ of 88.93 ± 4.72 and girls had a total IQ of 91.5 ± 5.6 ($t = -1.920$, $P = 0.06$). Girls had a higher mean of the comprehension subscale compared with boys (90.17 ± 6.43 vs. 87.03 ± 5.7, $t = -1.998$, $P = 0.05$) and a higher mean in performance abilities compared with boys (87.4 ± 7.26 vs. 83.83 ± 5.81, $t = -2.102$, $P = 0.04$). Other IQ subscales did not differ significantly between boys and girls.

Diagnosis, symptoms, and comorbidities

Table 1 shows that 50% of ADHD patients showed the combined type (CB), whereas 31.7% of patients showed the predominantly inattentive (PI) type and 18.3% showed the predominantly hyperactive type. In addition, it shows that 86.7% of boys had either the CB or the predominantly hyperactive type of ADHD, whereas 90% of girls had either the CB or the PI type of ADHD, showing a statistically significant difference, $P = 0.007$.

In all, patients had significantly higher scores (CPRS-R-L) than the controls, except for the anxious–shy subscale (Table 2). Boys showed higher means in the 'hyperactivity', 'Conners' Global Index total' and 'DSM-IV hyperactive–impulsive' subscales. Girls showed higher means in the 'cognitive problems/inattention', the 'psychosomatic', 'Conners' ADHD Index', and the 'DSM-IV inattentive' subscales (Table 3).

Table 4 shows the comorbidities; male and female patients did not differ in comorbid learning disabilities but differed in conduct disorder and depression.

Gender differences in executive functions

When testing the participants using WCST (Table 5), it was found that children with ADHD could reach the first sorting principle after the same number of trials as the control children ($P = 0.914$). However, compared with the normal controls, ADHD patients performed more trials to finish the test, made more errors, showed more perseveration responses whether correct or incorrect even when a feedback was given, were less successful in completing a set of five or more correct consecutive matches, completed less number of test categories, and showed less ability to learn, reflected in worsening efficiency across consecutive categories of the test ($P < 0.001$).

In terms of gender differences in EF (Table 6), girls with ADHD made more errors – not necessarily perseverative – during the test ($P = 0.050$) and were able to complete

Table 1 Attention deficit hyperactivity disorder subtype in male and female patients according to the DSM-IV criteria

	N (%)				
	Males (N=30)	Females (N=30)	Total (N=60)	χ^2	P
Predominantly inattentive type	4 (13.3%)	15 (50%)	19 (31.7%)	9.84	0.007
Predominantly hyperactive type	8 (26.7%)	3 (10%)	11 (18.3%)	–	–
Combined type	18 (60%)	12 (40%)	30 (50%)	–	–

Table 2 Conners' Parent Rating Scale-Revised-Long version in cases and controls

	Mean ± SD			
	Cases (N=60)	Controls (N=40)	t	P
(A) Oppositional	61.65 ± 12.05	45.48 ± 4.44	8.119	<0.001
(B) Cognitive problems/inattention	74.63 ± 12.05	44.8 ± 3.3	18.182	<0.001
(C) Hyperactivity	72.9 ± 17.42	46.48 ± 4.46	9.375	<0.001
(D) Anxious–shy	53.4 ± 12.6	51.3 ± 5.99	1.115	0.268
(E) Perfectionism	48.78 ± 10.88	44.5 ± 3.45	2.842	0.006
(F) Social problems	69.52 ± 15.76	49.2 ± 4.21	7.953	<0.001
(G) Psychosomatic	54.23 ± 10.86	50.23 ± 5.9	2.381	0.019
(H) Conners' ADHD Index	71.83 ± 9.47	44.25 ± 2.84	17.860	<0.001
(I) Conners' Global Index: restless/impulsive	77.97 ± 8.3	46.78 ± 3.43	25.963	<0.001
(J) Conners' Global Index: emotional lability	65.42 ± 10.67	47.43 ± 3.82	10.219	<0.001
(K) Conners' Global Index total	75.27 ± 9.35	45 ± 2.67	23.673	<0.001
(L) DSM-IV inattentive	69.65 ± 9.65	43.9 ± 2.87	16.376	<0.001
(M) DSM-IV hyperactive–impulsive	73.73 ± 13.22	46.85 ± 4.5	14.536	<0.001
(N) DSM-IV total	75.55 ± 10.11	45.35 ± 3.13	18.291	<0.001

Table 3 Conners' Parent Rating Scale-Revised-Long version in male and female patients

	Mean ± SD			
	Males (*N*=30)	Females (*N*=30)	*t*	*P*
(A) Oppositional	62.47 ± 10.1	60.83 ± 13.86	0.522	0.604
(B) Cognitive problems/inattention	69.83 ± 12.21	79.43 ± 9.94	−3.340	**0.001**
(C) Hyperactivity	78.43 ± 16.53	67.37 ± 16.77	2.575	**0.013**
(D) Anxious–shy	52.17 ± 13.11	54.63 ± 12.18	−0.755	0.453
(E) Perfectionism	46.83 ± 7.19	50.73 ± 13.47	−1.399	0.167
(F) Social problems	69.93 ± 15.43	69.1 ± 16.34	0.203	0.840
(G) Psychosomatic	51.33 ± 9.25	57.13 ± 11.7	−2.130	**0.037**
(H) Conners' ADHD Index	66.73 ± 7.45	76.93 ± 8.56	−4.924	< **0.001**
(I) Conners' Global Index: restless/impulsive	79.7 ± 6.93	76.23 ± 9.28	1.640	0.106
(J) Conners' Global Index: emotional lability	67.57 ± 11.25	63.27 ± 9.78	1.58	0.120
(K) Conners' Global Index: total	77.93 ± 6.94	72.6 ± 10.72	2.288	**0.026**
(L) DSM-IV inattentive	65.83 ± 8.3	73.47 ± 9.51	−3.313	**0.002**
(M) DSM-IV hyperactive–impulsive	77.6 ± 12.15	69.87 ± 13.32	2.350	**0.022**
(N) DSM-IV total	75.7 ± 6.25	75.4 ± 12.99	0.114	0.910

Bold numerals are statistically significant. DSM-IV, *diagnostic and statistical manual of mental disorders, 4th ed.*

Table 4 Comorbidities according to the DSM-IV-TR criteria in attention deficit hyperactivity disorder patients

	N (%)				
	Males (*N*=30)	Females (*N*=30)	Total (*N*=60)	χ^2	*P*
Learning disorders					
Reading disorder	18 (60%)	18 (60%)	36 (60%)	0.000	1.000
Disorder of written expression	17 (56.7%)	13 (43.3%)	30 (50%)	1.07	0.439
Mathematics Disorder	12 (40%)	7 (23.3%)	19 (31.7%)	1.92	0.267
Disruptive behavior disorders					
CD	8 (26.7%)	1 (3.3%)	9 (15%)	6.4	**0.026**
ODD	6 (20%)	6 (20%)	12 (20%)	0.000	1.000
Mood disorders					
Depressive disorders	0 (0)	7 (23.3%)	7 (11.7%)	7.93	**0.01**
Bipolar disorders	0 (0)	0 (0)	0 (0)	–	–
Anxiety disorders					
GAD	0 (0)	0 (0)	0 (0)	–	–
OCD	0 (0)	0 (0)	0 (0)	–	–
Separation anxiety disorder	0 (0)	1 (3.3%)	1 (1.7%)	1.01	1.000
Mixed anxiety depression	0 (0)	1 (3.3%)	1 (1.7%)	1.01	1.000
Tic disorders	0 (0)	0 (0)	0 (0)	–	–
Communication disorders					
Expressive language disorder	1 (3.3%)	0 (0)	1 (1.7%)	1.01	1.000
Mixed receptive expressive language disorder	0 (0)	0 (0)	0 (0)	–	–
Phonological disorder	1 (3.3%)	1 (3.3%)	2 (2.3%)	0.000	1.000
Stuttering	1 (3.3%)	1 (3.3%)	2 (2.3%)	0.000	1.000

Bold numerals are statistically significant. CD, conduct disorder; ODD, oppositional defiant disorder; GAD, generalized anxiety disorder; OCD, obsessive compulsive disorder.

Table 5 Wisconsin Card Sorting Test of cases and controls

	Mean ± SD			
	Cases (*N*=60)	Controls (*N*=40)	*t*	*P*
Number of trials	126.27 ± 4.94	94.58 ± 13.28	14.447[a]	< 0.001
Total number of errors	48.58 ± 13.39	23.6 ± 8.87	131.500[b]	< 0.001
Perseverative responses	31.22 ± 15.06	15.1 ± 6.77	348.500[b]	< 0.001
Percent perseverative responses	24.72 ± 11.76	15.6 ± 5.84	559.50[b]	< 0.001
Perseverative errors	27.87 ± 11.85	13.63 ± 5.54	290.000[b]	< 0.001
Percent perseverative errors	21.97 ± 9.15	14.08 ± 4.44	513.500[b]	< 0.001
Number of categories completed	3.68 ± 1.66	5.95 ± 0.32	261.000[b]	< 0.001
Trials to complete first category	15.13 ± 8.07	13.28 ± 5.19	1185.000[b]	0.914
Failure to maintain a set	1.98 ± 1.55	0.48 ± 0.68	490.500[b]	< 0.001
Learning to learn	−9.35 ± 10.24	0.14 ± 2.55	269.000[b]	< 0.001

Learning to learn item was not applicable in nine patients.
[a]Value of the *t*-test.
[b]Value of the Mann–Whitney test.

less number of test categories than boys ($P = 0.024$). There was no statistically significant difference between male and female patients in the rest of the WCST components. No difference in the scores of WCST components was found between male and female controls.

EFs did not correlate with the hyperactivity subscale of CPRS-R-L. It correlated with inattention (cognitive problems/inattention subscale of CPRS-R-L) in boys and girls (Tables 7 and 8).

Gender differences in reading

Table 9 shows that 95% of ADHD patients showed alphabet recognition appropriate for their age and IQ, whereas only 50% of ADHD patients showed word recognition, 38.3% showed fluent reading, 40% were good at spelling, 63.3% could copy a text, and 40% had handwriting appropriate for their age and IQ. In addition, it shows that there was no statistically significant difference between the male ADHD patients and the female ADHD patients in terms of their reading abilities.

Table 10 shows that, on the Metacognitive Reading Comprehension Scale, ADHD children in our study showed less awareness than controls on the importance of using different strategies during reading ($P<0.001$) and less ability to 'plan' and 'evaluate' using these strategies for a better understanding of the written text ($P<0.001$), but they were similar to controls in that their own perceptions and feelings about themselves as readers affected their understanding of the written text ($P=0.127$). There was no statistically significant difference between the male ADHD patients and the female patients in terms of performance on the Metacognitive Reading Comprehension Scale (Table 11). None of the WCST components predicted the Metacognitive Reading Comprehension total score in patients when entered with

Table 6 Wisconsin Card Sorting Test of male and female patients

	Mean ± SD			
	Males (*N*=30)	Females (*N*=30)	*t*	*P*
Number of trials	126.23 ± 4.62	126.3 ± 5.31	−0.052[a]	0.959
Total number of errors	45.13 ± 12.75	52.03 ± 13.32	317.500[b]	**0.050**
Perseverative responses	29.63 ± 16.14	32.8 ± 13.99	351.500[b]	0.145
Percent perseverative responses	23.73 ± 12.91	25.7 ± 10.62	352.000[b]	0.146
Perseverative errors	26.27 ± 12.67	29.47 ± 10.94	359.000[b]	0.177
Percent perseverative errors	20.73 ± 9.74	23.2 ± 1.58	360.000[b]	0.182
Number of categories completed	4.17 ± 1.62	3.2 ± 1.58	300.500[b]	**0.024**
Trials to complete first category	14.47 ± 7.79	15.8 ± 8.41	446.500[b]	0.958
Failure to maintain a set	1.97 ± 1.45	2 ± 1.66	447.500[b]	0.970
Learning to learn	−8.67 ± 9.96	−10.17 ± 10.74	274.000[b]	0.363

Learning to learn item was not applicable in two male patients and seven female patients. Bold numerals are statistically significant.
[a]Value of the *t*-test.
[b]Value of the Mann–Whitney test.

Table 7 Correlation of inattention (cognitive problems/inattention subscale of CPRS-R-L) with executive functions (components of WCST) in patients

	CPRS-R-L (cognitive problems/inattention subscale)								
	All			Males			Females		
	N	*r*	*P*	*N*	*r*	*P*	*N*	*r*	*P*
WCST: total number of errors	60	0.426	**0.001**	30	0.583	**0.001**	30	0.111	0.559
WCST: percent perseverative errors	60	0.439	< **0.001**	30	0.473	**0.008**	30	0.354	0.055
WCST: percent perseverative responses	60	0.389	**0.002**	30	0.426	**0.019**	30	0.335	0.071
WCST: number of categories completed	60	−0.548	< **0.001**	30	−0.582	**0.001**	30	−0.382	**0.037**
WCST: failure to maintain a set	60	0.031	0.816	30	−0.254	0.176	30	0.332	0.073
WCST: learning to learn	51	−0.330	**0.018**	28	−0.558	**0.002**	23	−0.041	0.852

Bold numerals are statistically significant. CPRS-R-L, conners' parent rating scale-revised-long version; WCST, wisconsin card sorting test.

Table 8 correlation of hyperactivity (hyperactivity subscale of CPRS-R-L) with executive functions (components of WCST) in patients

	CPRS-R-L (hyperactivity subscale)								
	All			Males			Females		
	N	*r*	*P*	*N*	*r*	*P*	*N*	*r*	*P*
WCST: total number of errors	60	−0.100	0.446	30	0.070	0.713	30	−0.012	0.590
WCST: percent perseverative errors	60	−0.082	0.533	30	−0.092	0.629	30	0.016	0.932
WCST: percent perseverative responses	60	−0.033	0.803	30	−0.063	0.742	30	0.061	0.748
WCST: number of categories completed	60	0.239	0.065	30	0.033	0.861	30	0.289	0.121
WCST: failure to maintain a set	60	−0.241	0.064	30	−0.230	0.222	30	−0.270	0.149
WCST: learning to learn	51	−0.001	0.994	28	−0.111	0.573	23	0.076	0.732

CPRS-R-L, conners' parent rating scale-revised-long version; WCST, wisconsin card sorting test.

Table 9 Clinical assessment of reading abilities in attention deficit hyperactivity disorder patients

	N (%)				
	Males (N=30)	Females (N=30)	Total (N=60)	χ^2	P
Alphabet (appropriate for age and IQ)	27 (90%)	30 (100%)	57 (95%)	3.16	0.237
Word recognition (appropriate for age and IQ)	17 (56.7%)	13 (43.3%)	30 (50%)	1.07	0.439
Reading fluency (appropriate for age and IQ)	11 (36.7%)	12 (40%)	23 (38.3%)	0.07	1.000
Spelling mistakes (appropriate for age and IQ)	12 (40%)	12 (40%)	24 (40%)	0.000	1.000
Copying text (appropriate for age and IQ)	19 (63.3%)	19 (63.3%)	38 (63.3%)	0.000	1.000
Handwriting (appropriate for age and IQ)	11 (36.7%)	13 (43.3%)	24 (40%)	0.28	0.792

IQ, intelligence quotient.

Table 10 Metacognitive Reading Comprehension Scale of cases and controls

	Mean ± SD			
	Cases (N=36)	Controls (N=40)	t	P
Self-monitoring score	10.78 ± 1.53	11.33 ± 1.56	−1.542	0.127
Planning of task parameters score	19.86 ± 2.21	27.43 ± 1.99	−15.733	<0.001
Assessment of strategies score	18.14 ± 2.4	26.25 ± 2.76	−13.686	<0.001
Total score	48.67 ± 3.87	65 ± 3.76	−18.662	<0.001

The Metacognitive Reading Comprehension Scale was not applicable in 24 cases because of the presence of reading disorder.

Table 11 Metacognitive Reading Comprehension Scale of male and female patients

	Mean ± SD			
	Males (N=19)	Females (N=17)	t	P
Self-monitoring score	10.89 ± 1.29	10.65 ± 1.8	0.470	0.642
Planning of task parameters score	19.32 ± 2.29	20.47 ± 2	−0.470	0.118
Assessment of strategies score	17.63 ± 2.85	18.71 ± 1.69	−1.392	0.174
Total score	47.84 ± 3.95	49.59 ± 3.95	−1.368	0.180

The Metacognitive Reading Comprehension Scale was not applicable in 11 male patients and in 13 female patients because of the presence of reading disorder.

age and sex in a linear regression equation. In a second equation, the total score was predicted only by the CPRS-R-L N scale (DSM-IV total) but not by its other subscales, IQ scales, sex or age (Table 12). The Metacognitive Reading Comprehension Scale was not applicable in 24 patients because of the presence of a reading disorder.

Discussion

Choice of participants

We chose participants starting from 8 years of age to enable confirmation of the diagnosis of a comorbid reading disorder, as children who have a reading disorder can usually be identified by the age of 7 years (Sadock and Sadock, 2007). In addition, we controlled for the socioeconomic standard as many studies have shown that it is highly correlated with reading achievement (Raz and Bryant, 1990; Bowey, 1995; Hecht *et al.*, 2000). We chose participants with an IQ equal to or above 85 to be able to diagnose reading disability if present as a comorbid condition with ADHD, as its diagnosis requires the exclusion of mental retardation.

Attention deficit hyperactivity disorder subtype and comorbidities

The distributions of ADHD subtypes in our sample are consistent with those in many previous studies that found that the CB of ADHD is the most common subtype, followed by the PI subtype, followed by the predominantly hyperactive subtype (Faraone *et al.*, 1998; Gadow *et al.*, 2000; Biederman *et al.*, 2002).

The majority of male ADHD patients showed the CB, whereas the majority of female ADHD patients showed the PI type of ADHD, which was further confirmed by the results of the CPRS-R-L, which showed that male patients had higher means on the ‘DSM-IV hyperactive–impulsive subscale’, whereas female patients showed more cognitive problems/inattention and higher means on the ‘DSM-IV inattentive subscale’. These findings are in agreement with those of many previous studies that have found that girls showed the PI type more frequently than boys, whereas boys showed the CB more frequently than girls (Gaub and Carlson; 1997; Weiler *et al.*, 1999; Hartung *et al.*, 2002). Biederman *et al.* (2005), however, found that there were no significant differences in the frequency of subtypes of ADHD between male and female patients with ADHD, with the CB emerging as the most prevalent type for both groups; the inattentive type was the next most common and the hyperactive/impulsive type was the least common for both sexes. This difference can be attributed to the sample source, as their study was conducted on nonreferred participants, unlike other studies, which were performed on clinic-referred children. The nonreferred male and female patients with ADHD did not differ in the DSM-IV subtypes of ADHD, psychiatric comorbidity, or treatment history. Their findings suggest that the clinical correlates of ADHD are not influenced by sex and that gender differences reported in groups of participants seen in clinical settings may be caused by referral biases.

Of the patients with ADHD, 60–100% have one or more comorbid disorders (Gillberg *et al.*, 2004). The highest

Table 12 Linear stepwise regression of variables predicting the Metacognitive Reading Comprehension total score in patients

Dependant variable	Independent variable	β	t	Significant t	Adjusted R^2	F	Significant F
Metacognitive Reading Comprehension: total score	CPRS-R-L: DSM-IV total	−0.361	−2.256	0.031	0.105	5.090	0.031

Variables not in the equation: sex, age, Stanford–Binet IQ subscales and total, other CPRS-R-L scales.
CPRS-R-L, conners' parent rating scale-revised-long version; DSM-IV, *diagnostic and statistical manual of mental disorders, 4th ed*; IQ, intelligence quotient.

rates of comorbidities in our sample were for the learning disabilities, followed by the disruptive behavior disorder, whereas mood and anxiety disorders and communication disorders came last. Our study is in agreement with other studies (Angold *et al.*, 1999; Gillberg *et al.*, 2004; Bauermeister *et al.*, 2007) in terms of the increased comorbidities with ADHD in the form of externalizing disorders, internalizing disorders, learning disabilities, and speech problems, but the reported rates of comorbidities in those studies of externalizing (42–90%) and internalizing (13 – 51%) disorders were considerably higher than those found in our sample. It seems that in the Egyptian culture, desire for learning and academic achievements drive parents to seek help more than, for example, depression or even conduct disorders. Clinical interviews indicated that male ADHD patients showed more comorbid conduct disorders (externalizing disorders) than female patients, whereas female patients showed more comorbid depressive disorders (internalizing disorders), but they did not differ in the rate of comorbidty with learning disorders. There are contradictory comorbidity findings in the ADHD-sex literature. Studies have found increased comorbid externalizing disorders among boys with ADHD compared with girls (Gaub and Carlson, 1997; Gershon, 2002; Biederman *et al.*, 2002; Thorell and Rydell, 2008) and increased comorbid internalizing disorders among girls with ADHD compared with boys (Gershon, 2002; Levy *et al.*, 2005). However, some studies have reported no gender differences in ADHD comorbidity with externalizing disorders (Levy *et al.*, 2005; Bauermeister *et al.*, 2007) and some studies have reported a higher frequency of comorbid internalizing disorders in boys with ADHD compared with girls (Gaub and Carlson, 1997; Thorell and Rydell, 2008). As for learning disabilities, some studies have reported the absence of significant differences between the sexes in the rates of learning disabilities (Biederman *et al.*, 2005; Karande *et al.*, 2007). Some have suggested that these disabilities would show higher comorbidity in girls with ADHD (Gaub and Carlson, 1997), whereas others have suggested that they would show higher comorbidity in boys with ADHD (Biederman *et al.*, 2002).

Gender difference in executive functions

The results of a meta-analytic study of WCST in children (Romine *et al.*, 2004) suggest that, across all of the studies, children with ADHD fairly consistently showed poorer performance as compared with children without clinical diagnoses of ADHD, as measured by percent correct, number of categories completed, total errors, and perseverative errors. This is in agreement with our results in which children with ADHD performed poorly in all WCST indices compared with controls (Table 5).

Girls with ADHD showed a poorer performance in the number of categories completed compared with boys, probably because of their increased total errors (Table 6). Further, inattention problems were significantly higher in girls (Table 3) than in boys.

The reason why girls with ADHD made more errors and thus completed less number of categories than boys with ADHD may be because of the severity and/or the type of inattention problems they had. Qualitatively different impairments in attention were suggested to be present in ADHD-CB and ADHD-PI children (Barkley, 1997).

It has been proposed that children with CB have a core deficit in inhibitory control such that they are unable (Barkley, 1997) or unwilling (Sonuga-Barke *et al.*, 1992) to forego an immediate response to a stimulus in favor of a delayed, more adaptive response. Disinhibition, however, does not appear to characterize children with PI type, who are more often described as sluggish, withdrawn, and hyporesponsive. The differences between subtypes in cognitive tempo point to potentially significant differences in the qualitative features of inattention, which suggest differences in etiology. Thus, whereas children with the PI type appear to be slow to orient and slow to respond to cognitive and social stimuli in their immediate surroundings, children with CB rapidly orient to novel external stimuli irrespective of relevance (Solanto *et al.*, 2007).

Studies that have attempted to differentiate the CB and PI subtypes found greater difficulty with inhibitory control in the CB (Hinshaw *et al.*, 2002; Nigg *et al.*, 2002; Huang-Pollock *et al.*, 2006; Solanto *et al.*, 2007), and a greater deficit in processing speed on visual–motor or visual search tasks in the PI type (Chhabildas *et al.*, 2001; Nigg *et al.*, 2002, Solanto *et al.*, 2007); however, neurocognitive tests were not always helpful in elucidating these differences. Studies ranged from few distinctions between subtypes (Nigg *et al.*, 2002) to challenging the idea that ADHD-PI is a subtype of ADHD because of distinctive performance (Derefinko *et al.*, 2008). A possibility may be that the DSM-IV criteria, as currently formulated, do not distinguish valid subtypes. In agreement with this possibility, Goth-Owens *et al.* (2010), in a recent study, found slower cognitive interference speed in ADD patients compared with ADHD-CB and controls, in which ADD patients were defined as those who fulfilled the DSM-IV-TR criteria for ADHD-PI but had two or fewer hyperactive/impulsive symptoms. On comparison, they did not find differences between the ADHD-PI (which allows up to five hyperactivity/impulsivity symptoms) versus ADHD-CB and controls.

As 40% of our female ADHD children were of the CB and 50% were of the PI type (Table 1), presumably both types of attention impairments were present in the female patients, leading to increased errors and decreased Categories Completed.

Categories completed correlated negatively with the CPRS-R-L (cognitive problems/inattention subscale) in both boys and girls (Table 7); hence, the difference may not be because of sex but rather because of the attention problems as a whole that were associated with the other components of WCST in boys (Table 7). Therefore, our results are not supportive of a robust difference in EF that can be attributed solely to sex.

In their review of the extant literature on the comparability of executive, inhibitory, and attentional deficits across boys and girls with ADHD, Seidman *et al.* (2005) concluded that gender differences do not exist in EF deficits in ADHD. However, the meta-analyses by both Gaub and Carlson (1997) and Gershon (2002) led to the conclusion that girls with ADHD show greater cognitive dysfunction than boys with ADHD, but their results were based on IQ scores without examination of the details of executive dysfunction.

Gender difference in reading

In 816 children from ADHD and control families, Rommelse *et al.* (2009) found that reading problems correlated moderately ($r = 0.38$, $P < 0.001$) with the ADHD phenotype. On studying EFs and motor functions as endophenotypes, both were modestly to moderately correlated with reading problems. Both endophenotypes cross-correlated modestly with reading problems in siblings of ADHD children. They concluded that reading disorders (among other problems) shared executive and motor problems on an endophenotypic level with ADHD. The disorders shared underlying general neuropsychological dysfunctions that may give rise to both ADHD and several associated domains. These shared neuropsychological dysfunctions explain why our ADHD patients had lower scores on the Metacognitive Reading Comprehension scale (Table 10) compared to controls and why their caseness predicted the Reading scale total score (Table 12). Although the participants who were assessed using the scale did not have 'crude' reading disabilities, their metacognitive reading abilities were still affected. We failed, however, to predict the score with the WCST scales or find a gender difference probably because of the small sample size.

The high comorbidity found in our sample of reading disorders and the absence of a gender difference (Tables 4 and 9) are consistent with the findings of most previous studies (Biederman *et al.*, 2005; Levy *et al.*, 2005; Karande *et al.*, 2007) that revealed that, although the reading ability in children with ADHD was significantly affected compared with that in normal children, obvious gender differences between girls and boys with ADHD with respect to their reading abilities could not be documented. The literature shows that reading disability is more prevalent in boys in the non-ADHD population (St Sauver *et al.*, 2001), but the finding that girls with ADHD have the same comorbid reading disability as boys with ADHD points out the wide difference in academic achievement between girls with ADHD and normal girls. Furthermore, neuropsychological deficits were most pronounced in girls with both ADHD and an learning disabilities (LD) than girls with only ADHD (Seidman *et al.*, 2006).

Implications

(1) Barkley (1997) and Brown (2006) claim that all patients with ADHD, not only those who score low on neuropsychological tests, have significant EF impairments and that developmental impairments in these EFs represent the main feature of ADHD. Follow-up studies show that EF impairment persists in girls (Hinshaw *et al.*, 2007) as well as in boys (Fischer *et al.*, 2005) through adolescence. Assessment of deficits through real-world measures in addition to neuropsychological tests is required to determine the impact of these deficits on everyday life so that specific interventions can be designed. Planning of interventions should take into consideration the possible qualitative differences in EF – for example, in attention – between children with ADHD.

(2) As scholastic achievements are of importance to families who seek help for their children, assessment of reading impairments in ADHD patients should take into account the fact that reading problems may have a metacognitive component that necessitates specific remedial therapies.

Recommendations

(1) It is recommended for future research of gender differences in ADHD to analyze differences in relation to subtypes (sex $\times$ subtype interaction) for a better understanding of the effect of sex on neuropsychological tests and comorbidities.

(2) More work is needed in both referred and nonreferred samples (community samples) of children with ADHD to assess the effect of sex on the clinical presentation of the disorder and its causation of a sex-based referral bias. The finding that girls with ADHD were less likely than boys with ADHD to have comorbid disruptive behavior problems and that the rate of symptoms of inattention was higher in girls with ADHD could have an unfavorable bias in the referral of girls.

Limitations

(1) The Metacognitive Reading Comprehension Scale was not applicable in 24 cases (more than one-third of the cases) because of its dependence on intact word

decoding, which was highly affected in ADHD cases. In addition, most of the children found it difficult to understand item numbers 3, 5, 16, and 17 in the test.

(2) We used WCST for EF, and although the test measures the ability to form, maintain, and shift the cognitive set and to inhibit a prepotent response, specific tests of the areas less tapped by WCST such as working memory, processing speed, impulse control, and planning were required to delineate the specific impaired EF.

(3) Our study was conducted on a small sample size of clinic-referred ADHD children who might be non-representative for all children with ADHD. As these results were cross-sectional, we cannot assess the longitudinal impact of sex on EF impairment in children with ADHD.

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Conflicts of interest

There are no conflicts of interest.

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