Executive dysfunction screening and intelectual coefficient measurement in children with attention deficit hyperactivity disorder

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ABSTRACT

Objective: To perform a complete Intelligence quotient (IQ) measurement (verbal, performance, and total) and subsequently, to compare executive function (EF) measurements in subgroups of children with attention deficit-hyperactivity disorder (ADHD) with a control group. **Method:** We studied a group of children from 7-12 years of age from public elementary schools. Children were selected by means of Diagnostic and Statistical Manual of Mental Disorders-IV-Revised (DSM-IV-R) parent and teacher questionnaires for ADHD. EFs were screened by Weschler Intelligence Scale for Children (WISC-R) performance intelligence quotient (IQ) determination of the following sub-tests: picture completion; block designs, and object assembly tests. Simultaneously, total (T–), performance (P–), and verbal (V–) IQs were measured for each patient. **Results:** We studied 26 control subjects, and 35 children with ADHD. Numbers of children in each ADHD sub-type group were as follows: 15 in the combined group (–C), 13 in the inattentive group (–I), and 7 in hyperactivity group (–H). We found significant lower EF scores in picture arrangement (F=3.76, df 3,57, p=0.01), block design (F=4.55, df 3,57, p<0.01), and object assembly (F=4.52, df 3,57, p<0.01). *Post-hoc* analysis showed that differences were located among ADHD-C, ADHD-I, and ADHD-H groups when compared with controls. We found significantly lower cognitive scores in the ADHD-I group as follows: P-IQ (F=3.57, df 3,57, p=0.02), and T-IQ (F=2.90, df 3,57, p=0.04). **Conclusion:** Our results showed that screening of EF alteration in children with ADHD is easy and rapid by means of certain P-IQ determination sub-scales of the WISC test; moreover, complementary IQ determination can be measured simultaneously. Overall, children with ADHD exhibited an EF alteration. ADHD-I children demonstrated lower P-IQ, and T-IQ scores than control children.
Key words: attention deficit hyperactivity disorder, intelligence quotient, executive dysfunction, school children.

Tamizaje de la disfunción ejecutiva y medición del coeficiente intelectual en niños con trastorno por déficit de atención-hiperactividad

RESUMEN

Objetivo: Realizar una medición global de cociente intelectual (CI) (verbal, ejecutivo y total) y comparar las funciones ejecutivas (FE) en los subgrupos de niños con trastorno por déficit de atención-hiperactividad (TDAH) con un grupo control. **Método:** Se estudiaron niños de 7-12 años, provenientes de escuelas oficiales primarias. Se les aplicó el cuestionario de criterios diagnósticos de TDAH del DSM-IV-R para padres y maestros. Las FE se tamizaron

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mediante las sub-escalas de: ordenación de dibujos, diseño con cubos y composición de objetos del WISC-R. En forma paralela se midieron los CI Verbal (–V), Ejecutivo (–E), Total (–T) de cada paciente. **Resultados:** Se estudiaron 26 niños control y 35 con TDAH. La distribución de niños con TDAH en los diferentes subtipos clínicos fue la siguiente: 15 niños con TDAH combinado (–C), 13 con inatención (–I) y 7 con hiperactividad-impulsividad (–H). Se encontraron calificaciones menores en las sub-escalas de: ordenación de dibujos (F=3,76, gl 3,57, p=0,01), diseño con cubos (F=4,55, gl 3,57, p<0,01) y en la composición de objetos (F=4,52, gl 3,57, p<0,01). El análisis *post-hoc* mostró que las diferencias se produjeron entre los grupos de TDAH-I, TDAH-H y TDAH-C en relación al de control. Encontramos calificaciones menores en el CI del grupo de TDAH-I en la siguiente forma: CI-E (F=3,57, gl 3,57, p=0,02) y CI-T (F=2,90, gl 3,57 p=0,04). **Conclusión:** Nuestros resultados muestran que las alteraciones de las FE pueden ser fácilmente tamizadas por WISC-R, además de medir simultáneamente el CI. Se encontró que los niños con TDAH de los 3 tipos muestran una disfunción de las FE. También se encontró que los niños con TDAH-I muestran menores puntajes del CI-E y CI-T que los controles.

Palabras clave: trastorno por déficit de atención, coeficiente intelectual, disfunción ejecutiva, escolares.

Attention deficit hyperactivity disorder (ADHD) is the most frequent neurodevelopmental alteration in children ≥4 years of age in many countries. ADHD prevalence is estimated in 5% in school- age children in the U.S.[1]. In Mexico, no epidemiological studies on prevalence have been carried out, but according to the Health Secretariat, ADHD is among the first places of pediatric psychiatry out-patient consultation; its prevalence has been estimated in 2 million school-age children[2]. Male children are affected 3-4 fold more than females.

One of the recognized problems in the examination to detect ADHD in children is the alteration of executive functions (EF). The EF concept is broad and variable, but overall it is used for the higher brain process involved in planning problem solving; organizing and making a choice, maintaining the response pattern in the working memory, selectively directing the attention, and inhibiting inadequate response. All of these functions engage frontal lobe functioning as described by Rossi et al. in the prefrontal cortex (PFC) and its connections with striatum and parietal cortex in switch attentional control on the basis of changing task demands in *Macaca mulatta*[3], and in humans by Rubia and colleagues, who showed that children with ADHD showed brain dysfunction compared with healthy controls in right orbitofrontal (successful inhibition) and left dorsolateral (failed inhibition) PFC[4]. Screening of EF alterations can be performed by means of the Wechsler Intelligence Scale for Children (WISC-R), which had a sub-test to measure perceptual organization, planning problem-solving, non-verbal reasoning, direction of attention, visual sequences, analysis and synthesis, visuo-motor coordination, mental processing speed, spatial relationships, and working memory[3]. This sub-test can be easy and rapid for the use of screening and de-

tecting ADHD in children who are suspected of having changes in EF, for the purpose of performing more specific and comprehensive evaluations such as the Stroop test and others later, during subsequent appointments.

It is widely accepted that children with ADHD do not have lower intelligence than control asymptomatic children. However, certain children with cognitive alterations may exhibit executive dysfunction, such as in the case of Down syndrome, mental retardation, and other diseases. Patients with these pathologies also demonstrate hyperactivity and attention disorders[5]. Thus, we thought that intelligence can play a significant complementary role in executive dysfunction in ADHD.

Our objectives for this research were the following: [1] to perform a complete Intelligence quotient (IQ) measurement (verbal, performance, and total) and [2] subsequently, to compare EF measurements in sub-groups of children with ADHD, mainly with inattention symptoms, mainly with hyperactivity-impulsivity, and with combined symptoms with a control group.

METHOD
Subjects

We designed a cross-sectional study. The sample comprised a group of children residing in Mexico City and suburban areas, of low-middle to middle socioeconomic strata and from public elementary schools. Inclusion criteria were 7-12 years of age and identification of ADHD, while exclusion criteria included mental retardation, epilepsy, hearing loss, other developmental neurologic or psychiatric alterations, and severe chronic disease with significant school absenteeism, or to have been examined by means of the WISC test in the last 6 months. All patients were ADHD medication-free and were asked prior

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to examination concerning any other drug consumption. We formed a control group with healthy asymptomatic children by employing the same inclusion, and exclusion criteria, but without a diagnosis of ADHD.

We sent questionnaires the American Psychiatric Association (APA) Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-R) questionnaires to the parents and teachers of children in the group. They were instructed on the meaning of each question, underscoring that the requested behavior must be observed in at least the last 6 months. To identify children with ADHD, we performed a multi-disciplinary examination with neurologic, psychologic, psychiatric, neuropsychologic, and neurophysiologic tests. The points of view of parents and teachers were also taken into account by means of DSM-IV-R questionnaires. Diagnoses were performed by means of the agreement on researchers of disruptive behavior of the child in at least two different environments. The control group was made up of asymptomatic children of the same age and schools without DSM-IV-R inclusion criteria for ADHD. ADHD was classified according to the three recognized DSM-IV-R sub-types as follows: ADHD combined (–C), mainly with inattention symptoms (–I), and mainly with hyperactivity-impulsivity (–H). This investigation was approved by the Research and Ethics Committee of the National Institute of Rehabilitation in Mexico City, and written informed consent was given by parents of participating children according to Declaration of Helsinki[6].

WISC-R

To screen EF and measure IQ in participating children, we applied the WISC-R test. This consists of a test of two sub-scales that can be combined to form a total intelligence quotient (T-IQ) score that measures general intelligence performance. The two sub-scales include the following: verbal, and intelligence performance sections. The verbal intelligence quotient (V-IQ) scale was divided into: information, similarities, arithmetic, vocabulary, comprehension, and digit span. The performance intelligence quotient (P-IQ) scale was divided into: picture completion, picture arrangement, block design, object assembly, coding, and mazes. Each sub-scale was considered independent, and data from the sub-scales was compared with data from the reference tables in the manual for each V-IQ, P-IQ, and T-IQ score calculation. T-IQ scores were classified in the following seven levels: ≥130, very superior; 120-129, superior; 110-119, normal-brilliant; 90-109, normal; 80-89, normal-awkward; 70-79, border-line; and ≤69, mental retardation[7].

EF was screening from data of the following P-IQ subtest: picture completion; picture arrangement; block designs; object assembly; coding, and mazes. These subtests evaluated perception organization, planning, non-

verbal reasoning, attention, visual sequences, analysis and synthesis, visuo-motor coordination, mental processing speed, spatial relationships, and working memory. All of these latter functions are part of EF.

Statistics

We measured the mean and standard deviation (SD) of continuous variables and percentages in binomial variables. Differences in binomial variables were compared by χ^2 test. We used one-way analysis of variance (ANOVA) to compare the means of three or more groups, with Tukey *post-hoc* test to locate differences between groups. Then, we calculated correlation values among psychometric data values by means of the Spearman method. We calculated sensitivity and specificity by means of 2×2 contingency tables. The *a-priori* alpha value accepted was p≤0.05. We utilize SPPS software version 14.0.

RESULTS

We studied 26 control children with mean ages of 9.4±2.3 (±SD) years; 73% were males and 27% females. The ADHD group comprised 35 children with a mean age of 9.2±2.1 years; 71% were males and 29%, females.

Correlation between parents and teachers in identifying children with ADHD with the DSM-IV-R questionnaire was significant (rho=0.58, p=0.01). The sensitivity and specificity of DSM-IV-R questionnaires for detecting children with ADHD compared with multidisciplinary diagnosis as the gold standard in the case of parents and guardians were 88, and 82%, respectively, while in the case of teachers, these were 83 and 81%, respectively. Distribution of patients in different types of ADHD subgroups was as follows: 15 children with ADHD-C, 13 with ADHD-I, and seven children with ADHD-H.

We found lower scores of EF in ADHD groups when compared with the scores of the control group in several sub-scales as follows: picture arrangement (F=3.76, df 3,57, p=0.01), block design (F=4.55, df 3,57, p<0.01), and object assembly (F=4.52, df 3,57 p<0.01). Tukey *post-hoc* analysis showed that differences were located between scores from the ADHD-I group when compared with those of the control group in picture arrangement; between ADHD-C and control group in block designs, and between ADHD-C, and ADHD-H with the control group in object assembly (Table 1).

V-IQ, P-IQ, and T-IQ scores were within normal range. The majority fell within the low-normal, normal, and high-normal range classifications. Children of the ADHD-I group had a higher frequency of low-normal IQ determinations. We found lower IQ scores in children with ADHD when compared with those in the control group as follows: in P-IQ (F=3.57, df 3,57, p=0.02); and in T-IQ (F=2.90, df 3,57, p=0.04). Tukey analysis showed

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Table 1. Executive function (EF) in control and in the attention deficit hyperactivity disorder (ADHD) group of children.

Sub-scale	Control × SD	ADHD-C × SD	ADHD-H × SD	ADHD-I × SD	F	p
Picture completion	8.9±3.7	7.6±4.7	10±4.1	5.1±3.2	3.76	0.01
Block design	10.6±2.6	8.1±3.9	7.7±4.7	7.8±2.8	4.55	<0.01
Object assembly	9±2.2	7.2±3.2	10.9±4.3	7±2.7	4.52	<0.01

x: mean; SD: standard deviation; ADHD-C: ADHD combined; ADHD-H: ADHD hyperactivity-impulsivity; ADHD-I: ADHD inattention.

Table 2. Comparison of WISC-R results in V-IQ, P-IQ, and T-IQ sub-scales in control and in children with attention deficit hyperactivity disorder ADHD.

IQ	Control × SD	ADHD-C × SD	ADHD-H × SD	ADHD-I × SD	F	p
V-IQ	108±20	101±22.8	109.5±22.2	88±12.4	1.95	0.133
P-IQ	112±16	100±26.5	112.9±22.5	88±11.5	3.55	0.020
T-IQ	110±18	101±25.7	111.8±23.3	87±11.5	2.90	0.043

IQ: intelligence quotient ; x: mean; SD: standard deviation; V-IQ: verbal intelligence quotient ; P-IQ: picture intelligence quotient ; T-IQ: total intelligence quotient; ADHD-C: ADHD combined; ADHD-H: ADHD hyperactivity-impulsivity; ADHD-I: ADHD inattention.

Table 3. Correlation between intelligence quotient (IQ) and attention deficit hyperactivity disorder (ADHD) scores of DSM-IV-R for each group.

	ADHD-C	ADHD-I	ADHD-H
V-IQ	r=0.58 p=0.08	r=0.61 p=0.02	r=0.74 p=0.06
P-IQ	r=0.09 p=0.73	r=0.02 p=0.94	r=0.38 p=0.39
T-IQ	r=0.01 p=0.99	r=0.29 p=0.33	r=0.63 p=0.12

V-IQ: verbal intelligence quotient; P-IQ: picture intelligence quotient ; T-IQ: total intelligence quotient ; ADHD-C: ADHD combined; ADHD-H: ADHD hyperactivity-impulsivity; ADHD-I: ADHD inattention.

that differences were located between the ADHD-I and the control group (Table 2).

We observed a significant correlation between V-IQ scores and DSM-IV-R scores in the ADHD-I group (see Table 3). We also observed a nearly significant correlation between the V-IQ score and the DSM-IV-R score in the ADHD-H group (Table 3).

DISCUSSION

The main findings of the present research were: [1] children with ADHD present EF alterations that can be screened with some WISC P-IQ sub-tests; and [2] we observed lower T-IQ and P-IQ within normal range in children with ADHD when compared with their peers.

Data from our comparisons showed that EF were altered in children with ADHD, especially in the following sub-tests: pictures arrangement, block design, and object assembly. These sub-tests evaluate perception organization, planning, non-verbal reasoning, visual sequences, analysis and synthesis, visuo-motor coordination, mental processing speed, spatial relationships, and working memory. All these actions depend on and are part of EF and frontal lobe function. EF alteration has been demonstrat-

ed many times in the clinical literature in children with ADHD. The first researcher to recognize this relationship was Pontius, who called attention to the analogy between frontal lobe dysfunction and minimal cerebral dysfuntion[8]. In the same research line, Mattes showed evidence of frontal dysfunction in hyperkinetic children,[9] and afterward, Lazar and Frank made the same observation[10]. At present, controversy focuses on which EF are altered, and in which ADHD subtype in children with the disorder.

Many studies that investigated EF alteration in children with ADHD have reported variable results. In the first place, the EF concept is different among studies; thus, comparisons of findings is difficult with our data. Second, the different methodologies that have been employed for conducting comparisons are limited among several publications. The majority of studies measure EF by means of clinic psychometric and neuropsychologic tests, but other authors have utilized functional-magnetic resonance imaging (fMRI)[11], or event related potentials (ERP)[12]. Age at time of study was also heterogeneous. However, despite all odds, there is an agreement of EF alteration in children with ADHD in several ways[4,8-18]. Psychometric tests employed to study EF in other investigations have been variable, but in agreement with our results, the authors found lower scores in children with ADHD when compared with those of children in the asymptomatic control group. Our results demonstrated measurement of the WISC-R P-IQ sub-scale in picture arrangement, block designs, and object assembly; can be used to screen EF alteration in children with ADHD in order to carry-out a more comprehensive EF examination later during subsequent appointments.

The usefulness of WISC intelligence measurement in our study's children showed significantly lower scores in P-IQ and in T-IQ in children in ADHD-I sub-group. Our observations are in agreement with the results of Bara-Jiménez[13] et al., who found that children with ADHD-I had

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a lower T-IQ within normal range than controls, and that alteration of perception of speed was related with P-IQ. However, other studies are conservative and suggest that a low IQ score does not result in ADHD alteration, and that these patients usually had normal or higher IQ scores than the average child[19].

One point merits additional comments. Although it is accepted that children with ADHD do not have abnormal lower intelligence despite their being screened for mental retardation or other neurodevelopmental alteration, children with ADHD-C and ADHD-I in our sample showed significant lower V-IQ, P-IQ, and T-IQ scores when compared with controls, but these scores fell within normal range. However, this observation suggests a complex interaction between intelligence and EF measurements in children with ADHD. For example, Wodka et al.[20] found a significant interaction for verbal fluency total repetition errors with gender and the ADHD subtype. Boys with type ADHD-C type performed better than ADHD-C girls, whereas girls with the ADHD-I type performed tasks better than ADHD-I boys. Results from this study suggested that interaction between EF and ADHD type and gender must be taken into account in ADHD evaluation. Tillman et al.[21] studied EF (working memory, inhibition, and sustained attention) and non-EF (short-term memory, and processing speed) in a group of children with ADHD. They found that children with ADHD had poorer fluid intelligence; deficits were not fully mediated by -but rather extended beyond- poorer functioning in the EF and non-EF components. These investigators suggested that these alterations in children with ADHD represented deficiencies in general intellectual resource, reflecting executive attention processes. These latter results are in partial agreement with our data. There are empirical interrelationships among the three phenomena: ADHD, intelligence, and EF. Thus, intelligence test examinations in children with ADHD must be carefully interpreted, because there may be more than intellectual deficiencies in children with ADHD beyond executive dysfunction.

The effects of other comorbid diseases in our results appear unlikely, because we discarded study of children with conduct disorder, defiant oppositional disorder, and others. Moreover, these changes also appear to have other neurobiological bases that are different from those observed in children with ADHD and not including EF, as has been shown by fMRI in children with conduct disorder[4].

Our study had several limitations. The number of studied children is small, and the study utilized a cross-sectional design instead of a more powerful prospective design. Thus, it is noteworthy that the results of this study are not conclusive. Our protocol will continue to increase the sample of subjects under observation in order to re-

port other alterations in children with ADHD in up coming papers.

In conclusion, our investigation showed the usefulness of rapid, and easy EF alteration screening, which can be tested simultaneously with cognitive performance of children with ADHD by means of certain P-IQ item measurements at the same time as measurement of the WISC-R test.

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